TP7809

PHASE I INTERIM REPORT
FOR THE DESIGN AND DEVELOPMENT
OF THE CANADIAN ADVANCED RAILBUS

BY

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17. Abstract

Phase I for the Design and Development of the Canadian Advanced Railbus covers the preliminary design of the vehicle, setting of operating targets, and analysis of its performance with respect to these targets. The regulatory and operational requirements were studied for typical remote service applications with the conclusion that a safe and reliable operation can be achieved with a modified highway coach equipped with a rail wheel and suspension system. Some regulations for conventional rail rolling stock, such as requirements for couplers and buff loads, were analyzed, with the conclusion that they were not applicable in the remote-service environment.

The technical studies included review of stability, ride, curving, propulsion, braking, weight and balance, as well as the options for achieving bi-directional operation. It was concluded that vehicle stability could be achieved with a simple suspension system. Cross-bracing between the axle subframes is recommended in order to achieve a ride comparable to conventional rail coaches at targeted speeds of up to 100 km/h. Fuel consumption would be 23.4 l/100 km (12.1 mpg) at average service speeds of 50 to 70 km/h.

The vehicles are estimated to cost approximately $360,000 in a single unit bi-directional configuration with two driving positions, and $645,000 as a married pair arranged back-to-back with one unit being a freight vehicle.

The Phase I conclusion is that the Railbus is technically feasible and can be designed to meet all remote service operational requirements under benign and severe weather conditions.

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17. Résumé

Ce rapport concerne le programme d'étude et de réalisation au Canada d'un railbus de type avancé, dont la phase I a comporté l'étude des besoins, la définition des objectifs et l'analyse des performances. Il fait un tour d'horizon des exigences opérationnelles, réglementaires et techniques devant rendre ce véhicule apte à la desserte des régions reculées. Il montre que les besoins définis peuvent être satisfaits en toute sécurité et fiabilité par un railbus formé de la carrosserie d'un autocar et équipé d'une suspension, d'essieux et de roues de type ferroviaire. A propos de certains règlements, comme ceux concernant la résistance en compression et la standardisation de l'attelage, applicables au matériel roulant classique, il arrive à la conclusion qu'ils cessent d'être impératifs dans le cas d'un matériel destiné à la desserte des régions reculées.

L'aspect technique de l'étude a porté sur des paramètres tels que stabilité, confort de roulement, inscriptions en courbe, propulsion, freinage, équilibrage de la masse et réversibilité de la marche. La stabilité pourrait être assurée par une suspension simple, mais il a été recommandé de procéder à l'étude d'un bogie à liaison croisée des essieux afin d'obtenir un confort de roulement comparable à celui d'un matériel roulant classique à des vitesses pouvant atteindre 100 km/h. La consommation serait de 23,4 litres aux 100 km (12,1 mi/gallon) aux vitesses moyennes de 50 à 70 km/h. Le coût de production serait de l'ordre de 360 000 $ pour une voiture réversible avec poste de conduite à chaque extrémité, et de 645 000 $ pour une rame réversible de deux voitures, dont l'une transporterait du fret.

A l'issue de la phase I, la conclusion est que le railbus constitue un matériel apte à la desserte des régions reculées et peut être adapté à toutes les conditions climatiques prévisibles.

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SUMMARY

This report describes the work carried out during Phase I of a four-phase program to design and develop the Canadian Advanced Railbus. This initial phase was concerned with the assessment of requirements, preliminary design, and theoretical analysis of the vehicle to establish specifications, and technical and operational feasibility. Phase II of the program will be the detailed design and construction of the vehicle, which will be based on a Motor Coach Industries MCI 102A2 highway coach modified with suitable suspension, rail axles and wheels. In Phases III and IV of the program, the vehicle will be tested extensively on the Kingston test site and at a remote northern site.

The work carried out in Phase I started with a background review of existing Railbus technology including operating experience with the Winnipeg Coach Sales and Service (WCSS) modified Flyer bus. In order to develop an overall target specification for the vehicle, this review was combined with an analysis of the operating requirements for remote services as well as a review of the regulatory and railway technical requirements.

During the course of the Phase I preliminary design work, the performance of the vehicle was analysed with respect to the performance targets. Engineering concepts for the modification hardware were developed, taking into account cost, weight, compatibility with the envelope constraints, and the desired function. The hardware modifications to the base bus that were investigated include:

- Rail suspension, including wheels and axles
- Driveline and propulsion
- Brakes
- Special equipment such as snow-plow, lights, horns, etc.
- Means of obtaining bi-directional operation

This last item was critical to acceptability of the vehicle as defined by one potential operator, VIA Rail. The study team concluded that track-based systems for turning the vehicle were not sufficiently flexible. A detailed study of a vehicle-mounted turntable revealed that although it was technically feasible it was not operationally desirable. The preferred and recommended options for obtaining bi-directional operation were the use of a second driver's position on the preproduction prototype vehicle and a back-to-back married pair for production vehicles where additional capacity was required. This option is preferred on technical, operational, and market-penetration grounds.

The following conclusions are based on the work performed in Phase I of the program:

- The remote services requirement for a passenger vehicle can be met by a railbus based on the conversion and modification of a conventional intercity highway coach, such as the MCI 102A2, built in Winnipeg, Manitoba.

SUMMARY CONT'D

- There are no technical reasons identified to date that would render infeasible such a conversion.

- The engineering study of a vehicle based on the MCI 102A2 highway coach indicates that the recommended modified vehicle could meet all regulatory requirements existing for conventional rolling stock except those for buff load and conventional coupling.

- Not all of the currently specified equipment such as bells, handholds, etc. should necessarily apply in their entirety to a Railbus product. Some equipment standards should be waived or modified for this vehicle type and application. It is concluded that full public safety could be maintained without some of these requirements for conventional rolling stock.

- A simple suspension design would meet stability requirements but result in a degraded lateral ride with respect to current conventional equipment. The lateral ride would be roughly equivalent, and vertical ride would be superior to the ride of the current WCSS prototype vehicle. A more sophisticated design with cross-bracing between the single axles would achieve acceptable stability with ride equivalent to conventional equipment in both axes.

- The selected 229 kW (305 HP) Detroit Diesel Allison 6V92-TA engine combined with a 4-speed automatic transmission with lock-up in the top three gears will achieve the required maximum speed and climb a 3% grade at 80 km/h at full accessory load - an improved performance relative to imported vehicles.

- Fuel consumption will be 22.6 l/100 km (12.5 mpg) empty and 23.4 l/100 km (12.1 mpg) fully loaded on typical northern remote services, with average speeds in the 50 to 70 km/h range. This fuel consumption is considerably less than that for conventional equipment or RDCs.

- Tread brakes and actuators are available off-the-shelf for this application and can be activated by the coach air system.

- Vehicle weight empty will increase from the baseline 12,400 kg to 14,500 kg and fully loaded weight from 16,600 kg to 19,000 kg. Weight distribution will be 42.5% on the front axle and 57.5% on the rear axle.

- Wheel sanders will be fitted if proven to be required by operational testing. There is more than adequate space for such an installation.

- The preferred method of obtaining bi-directional operation is to install a second driver position in the rear of the prototype/ preproduction vehicle. For many applications, a back-to-back consist

SUMMARY CONT'D

with one unit being a freight vehicle is a logical solution. For a single unit, provision for a baggage trailer is required.

- Production vehicles in small batches of up to 20 units will cost approximately $360,000 for a single bi-directional unit, and $645,000 for a married pair with one being a freight unit. A simple freight trailer for use with the bi-directional single unit would cost approximately $20,000.

- Brake slide protection may not be required but could be fitted based on test results.

- There are applications for up to 20 such units in the remote service field.

It is recommended that:

- Work proceed immediately in the Phase II program to carry out detail design and construction to meet the design specification of Attachment A-3.

- Suspension design work focus on a cross-braced solution to the stability/ride trade-off issue.

- The preproduction prototype vehicle be constructed with two driving positions.

Note:

The program has been Terminated For Convenience by Transport Canada on the understanding that it will remain in abeyance until a decision by Transport Canada is made on the direction Railbus Technology will take in Canada. This decision is currently anticipated to take place in early spring 1987.

SOMMAIRE

Le présent rapport décrit les travaux de la phase I d'un programme échelonné sur quatre étapes, visant la conception et la réalisation d'un railbus de type avancé, au Canada. Cette phase a comporté l'étude des besoins, les études préliminaires et l'évaluation théorique devant vérifier la faisabilité du véhicule concerné. La phase II du programme portera sur l'étude détaillée ainsi que sur la réalisation du véhicule, lequel sera formé de la carrosserie d'un autocar MCI (Motor Coach Industries) 102A2 modifiée, équipée d'une suspension, d'essieux et de roues de type ferroviaire. Quant aux phases III et IV, elles concerneront les essais intensifs du matériel tant sur le tronçon d'essai à Kingston que dans région reculée.

La phase I a commencé par un tour d'horizon des technologies existantes et la prise en compte du résultat dégagé par le railbus réalisé par la Winnipeg Coach Sales and Services (WCSS), à partir d'un autocar Flyer modifié. Pour arriver à une définition précise du véhicule enfisagé, ce tour d'horizon a été complété de l'analyse des exigences opérationnelles, réglementaires et techniques devant rendre le véhicule apte à la desserte des régions reculées.

A l'étape des études préliminaires, les caractéristiques du véhicule ont été définies par rapport aux performances attendues. Les ingénierus ont également étudié les diverses composantes nécessaires à la réalisation du véhicule modifié, prenant en compte lesa paramètres de coût, poids, sujétions dimensionnelles et fonctions à remplir. Les points étudiés ont comporté notamment ce qui suit:

- la suspension de type ferroviaire, y compris les essieux et les roues,
- le système propulsif et la chaîne cinématique,
- les freins,
- les équipements tels que chasse-neige, feux de signalisation, avertisseurs, etc.,
- la réversibilité du véhicule.

Ce dernier paramètre est important du fait qu'il est considéré comme une condition sine qua non par un exploitant éventuel, VIA Rail. L'étude a montré qu'une table tournante sur voie n'offrait pas toute la souplesse voulue. Quant à une table tournante intégree au véhicule, elle n'était pas souhaitable du point du vue exploitation, bien qu'elle soit techniquement réalisable. La solution privilégiée a été celle de prévoir un deuxième poste de conduite sur la prototype pré-série et une configuration de rame réversible pour les véhicules de série mis en service là où la capacité devant la demande eat plus forte. Cette solution est considérée comme la meilleure sur la plan technique, opérationnel et de la commercialisation.

SOMMAIRE (SUITE)

Les travaux de la phase I ont débouché sur les conclusions suivantes:

- Les besoins concernant un matériel roulant voyageurs pour la desserte desa régions reculées seront satisfaits par un railbus formé de la carrosserie d'un autocar MCI 102A2, du type construit par la WCSS, et adapté au ferroviaire.

- Aucune raison d'ordre technique ne s'oppose à une telle modification.

- Les études techniques d'un tel matériel montrent que celui-ci pourrait satisfaire à la réglementation relative au matériel roulant classique, à l'exception des dispositions concernant la résistance en compression et la standardisation de l'attelage.

- Les accessoires tels que cloches, poignées, etc., obligatoires pour le matériel roulant classique, pourraient ne pas l'être pour le railbus, certains pouvant être écartés ou modifiés en conséquence, sans que la sécurité en soit compromise.

- Une suspension simple répondrait aux exigences de stabilité mais au détriment du confort de roulement qui tomberait alors au niveau du prototype actuel du railbus appartenant à la WCSS. La liaison croisée des essieux, par contre, offrirait un confort équivalant à celui d'un matériel classique.

- Le moteur choisi développant 299 kW (305 HP) et relié à une transmission automatique à 4 démultipications avec verrouillage des vitesses, sauf la première, donnera la vitesse maximale voulue et permettra de franchir des rampes de 3 p. 100 à la vitesse de 80 km/h à pleine charge, ce qui constitue une performance supérieure à celle des véhicules d'importation.

- La consommation sera de 22,6 litres (12,5 mi/gallon) et 23,4 litres (12,1 mi/gallon) aux 100 km, en marche à vide et à pleine charge, respectivement, dans les cas types de desserte des régions reculées, la vitesse moyenne s'établissant entre 50 et 70 km/h. Cette consommation est de beaucoup inférieure à celle d'un matériel classique ou d'un autorail diesel également classique.

- Les actionneurs du frein à air comprimé, disponsibles sur le marché, peuvant être manoeuvrés par pression dans le circuit d'air comprimé du railbus.

- Le poids à vide passera de 12 400 kg (poids du véhicule de base) à 14 500 et, à pleine charge, de 16 600 à 19 000 kg, le poids étant réparti à raison de 42,5 et 57,5 p. 100 sur l'essieu avant et arrière, respectivement.

SOMMAIRE (SUITE)

- Des sablières pourront être ajoutées si les essais in situ en montraient la nécessité, l'espace nécessaire étant actuellement plus qu'il n'en faut.

- La réversibilité de la marche pourra être obtenue par l'adjonction d'un deuxième poste de conduite sur le prototype pré-série, mais la meilleure solution consisterait à opter pour une rame réversible.

- Le coût de production série, en lots d'au plus 20 unités, serait de l'ordre de 360 000 $ pour une voiture réversible et de 645 000 $ pour une rame réversible de deux voitures, dont l'une transporterait du fret. Une remorque pour le transport du fret attelable à la voiture simple réversible coûterait autour de 20 000 $.

- Un dispositif anti-enrayage des freins pourrait être installé si les essias in situ le justifiaient.

- Un marché existe pour un maximum de 20 unités pour la desserte des régions reculées.

Il est donc recommandé:

- de passer sans tarder à la phase II du programme: étude en détail et réalisation conformément à la spécification donnée à l'annexe A-3,

- d'étudier une liaison croisée des essieux qui offrirait un meilleur compromis entre stabilité de marche et confort de roulement, et

- de réaliser un prototype de pré-série comportant un poste de conduite à chaque extrémité.

Transports Canada a mis fin au programme pour motif de commodité administrative, étant entendu qu'il redémarrera lorsque le ministère aura pris une décision définitive quant à la filière à privilégier en ce qui concerne la technologie des railbus au Canada. En principe, cette décision devrait être prise au début du printemps 1987.

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1.0 INTRODUCTION

1.1 BACKGROUND

No Canadian railbus vehicle is now available that is acceptable for use in general passenger service. A used Western Flyer bus has been converted for operation on railway tracks by Winnipeg Coach Sales and Service (WCSS) Ltd. This is a 30-year-old vehicle, however, solely intended to serve as a test vehicle to resolve institutional and regulatory issues, to evaluate related engineering design concepts, and to assess the overall feasibility of railbus operations in northern remote communities.

There are a few vehicles that have been developed overseas and that are available for import. Generally, these have not been designed for conditions found in Canadian remote service routes. Their suspension and component systems are not designed/optimized for Canadian track quality, which is oriented to heavy freight operation. Winterization is not adequate for Canadian weather conditions. Parts, materials, mechanical and electrical systems are generally of foreign manufacture, and the use of these vehicles would require separate and larger inventories to compensate for lengthened delivery times. Maintenance training and practices would also have to be adjusted to allow for non-standard equipment.

The Canadian Railbus will be designed to meet the following preliminary operating and technical requirements:

- Capable of one-man operation, local driver with highway bus experience and trained in railway operating procedures;
- Conventional bus maintenance using common North American bus parts;
- Conventional bus seating, with comfort, capacity and air quality levels achieved by the most recent and advanced highway coach technology;
- Accessible to the elderly and handicapped;
- Seating for approximately 40 people;
- Sufficient baggage space to accommodate 40 passengers;
- Accommodate connection of a baggage trailer to allow movement of items commonly transported in Northern Canada;
- Speeds up to 100 kph (60 mph) in forward direction;
- Low-cost maintenance of suspension parts;
- Minimum engineering redesign of bus suspension;

- o Energy consumption levels lower than the road version;
- o Target costs less than potentially suitable foreign technology;
- o Minimum changes to standard production bus designs; and
- o Small manufacture and assembly cost additions over base bus.

1.2 PROJECT SCOPE OF WORK

The scope of the work includes the analysis, design, construction, test and demonstration of a prototype advanced Canadian railbus vehicle. The work will be carried out in four phases over a period of 15 months, with the project scheduled for completion in March 1987.

Phase I is the "Preliminary Design and Specification" phase in which the operational requirements for the vehicle have been defined and the technical and operational solutions to meeting these requirements explored. Considerable theoretical analysis and a review of existing vehicles and other projects have been carried out. This phase has resulted in a complete preliminary design and specification for the vehicle.

Phase II encompasses the detail design and construction of the prototype railbus based on an existing new production MCI intercity coach. The rail wheels and axles will be modified components used on UTDC light rail production vehicles. This phase will produce a prototype railbus vehicle which has undergone functional testing of all major systems and a preliminary track test to verify the overall concept.

In Phase III detailed systematic testing will be carried out to a previously agreed plan to demonstrate compliance with the vehicle specifications. This test phase will be carried out at the UTDC/TTL test centre in Kingston. Factors that will be tested include such critical features as ride, stability, curving, fuel consumption, etc.

In the final part of the program (Phase IV) the vehicle will be shipped to a northern test site for winter testing over a period of several months. During this period, the operational aspects of the vehicle, including reliability and ride, will be demonstrated and the operating costs will be determined. Final Acceptance by TDC will conclude this phase.

Note: Due to Project Termination For Convenience by Transport Canada, the project scope addressed herein is limited to Phase 1 plus associated concluding activities.

1.3 PROJECT OBJECTIVES

1.3.1 Overall Objective

To develop technology suitable for rail services to remote communities where conventional rail service is extremely costly and suitable alternative modes of transportation are not available.

1.3.2 Project Objectives

To design, build, and test a preproduction prototype Canadian railbus vehicle of advanced design, conduct tests to demonstrate its performance, and obtain certification that the vehicle is acceptable for passenger-carrying service on the CN Rail line between Thompson - Pikwitonei - Thicket Portage.

The prototype vehicle will have the following as its design objectives:

- Ride comfort that is comparable to that of modern, well-maintained railway coaches presently operating in Canada.
- Reliability that is comparable to that of the standard, modern, highway coach.

1.4 OVERALL METHODOLOGY

During the program, two proven technologies, namely the MCI highway coach and UTDC rail vehicle technology, will be combined to create a railbus of significantly lower weight and cost than traditional rail vehicles. The key area of development will be the suspension system, which will have the demanding task of maintaining vehicle stability and safety while eliminating the possibility of feeding forces into the coach structural shell which would be beyond its current design capability.

There have been two major thrusts of development in Phase I, which to some extent parallelled each other. The first was to develop the technical and regulatory requirements of the vehicle in detail, based on reviews of industry practice, consultation with existing operators (Canadian National Railways (CN), VIA, etc.), and the consultation of the regulatory bodies themselves (Canadian Transport Commission (CTC), etc.). The second was the technical work, which consisted of generating ideas, and then testing of these ideas by means of analysis against the technical and regulatory requirements for the vehicle.

The theoretical design of the suspension system has been derived through the use of TTL's existing computer suspension model, which currently is used to design rail vehicle systems. In this model, the vehicle is represented as a system of rigid masses, each with

several degrees of freedom, interconnected by parallel elastic and viscous elements. Typical rail vehicles under analysis have incorporated 20 mass elements, 70 degrees of freedom, and over 100 suspension components and interconnections. Interaction forces and power spectral density curves characterizing wheel and rail surfaces are provided as input to the model to predict vehicle ride, stability, wheel unloading, curving ability, and ground-borne vibration.

Phase I has culminated in a detailed specification for the vehicle, and an Interim Report (this document). This Interim Report has been reviewed by Industry and Government representatives and the final version incorporates the results of that review process.

The Phase II activities concentrate on the vehicle modification. A standard MCI 102A2 coach will be purchased, complete with all running gear. It will be instrumented as a road vehicle, and some baseline data obtained on ride comfort and noise levels. After these tests, the following standard road equipment will be removed and returned to MCI:

- Road wheels and tires;
- Front and rear axles and brakes;
- Front and rear suspension systems;
- Steering system; and
- Front bumper.

In parallel with MCI construction of the coach, detail design drawings will be prepared for the modification hardware. This hardware will include:

- Rail wheels, axles, and brakes;
- Rear drive gearbox and transfer case;
- Subframes for axle location;
- Suspension elements;
- Lights, bells, etc.,
- Snow-plow; and
- Tow hitch for trailer.

The vehicle will then be instrumented and various functional tests carried out on systems such as the brakes, followed by preliminary test track operation.

Phase III encompasses the development testing at the TTL Kingston test site. This testing will start with performance measurements such as speed and acceleration, gradeability, noise levels (both interior and exterior), and performance of subsystems such as brakes, lights, heating and air conditioning, and exterior warning devices (horns, etc.). The ride and stability of the vehicle will then be investigated and safe operating speeds determined. Based on this test information and on the documentation of the vehicle's design and construction, application will be made to the Canadian Transportation Commission for acceptance of the vehicle for its test operation on a defined railway line.

Phase IV testing will be extensive and carried out on a private railway line under northern conditions that are representative of winter operation in remote service applications. Ride, noise levels, performance, and safe operating speeds will all be investigated in the northern environment. The project will culminate in delivery of the vehicle to Transport Canada for further demonstration purposes and preparation of a final report.

1.5 SCHEDULE

A detailed program schedule is shown in Figure 1. The program is scheduled to take 15 months with a completion date of March 31 1987. A commitment to vehicle purchase in March and stress analysis work by MITC was required in order to meet the overall schedule constraints. Work will proceed on a low-level interim basis between Phase 1 and 2 awaiting official approval to proceed.

1.6 ORGANIZATION OF THE REPORT

This report describes the activities and related conclusions and recommendations of Phase I of the project. The report includes as Section 2.0 a review of applicable vehicle, technology, the service requirements for the vehicle and the regulatory requirements within which the vehicle must operate. In Section 3.0 the technical approaches are discussed and solutions proposed for each of the features of the converted railbus. In Section 4.0 the resulting conceptual design work for the conversion is described, and in Section 5.0 a Design Specification is discussed. The detailed design specification is included as Attachment A-3. Also included as attachments are a portfolio of design drawings (A-2), the detailed task report investigating the service requirements (A-1), and the results of the review meeting (A-4).

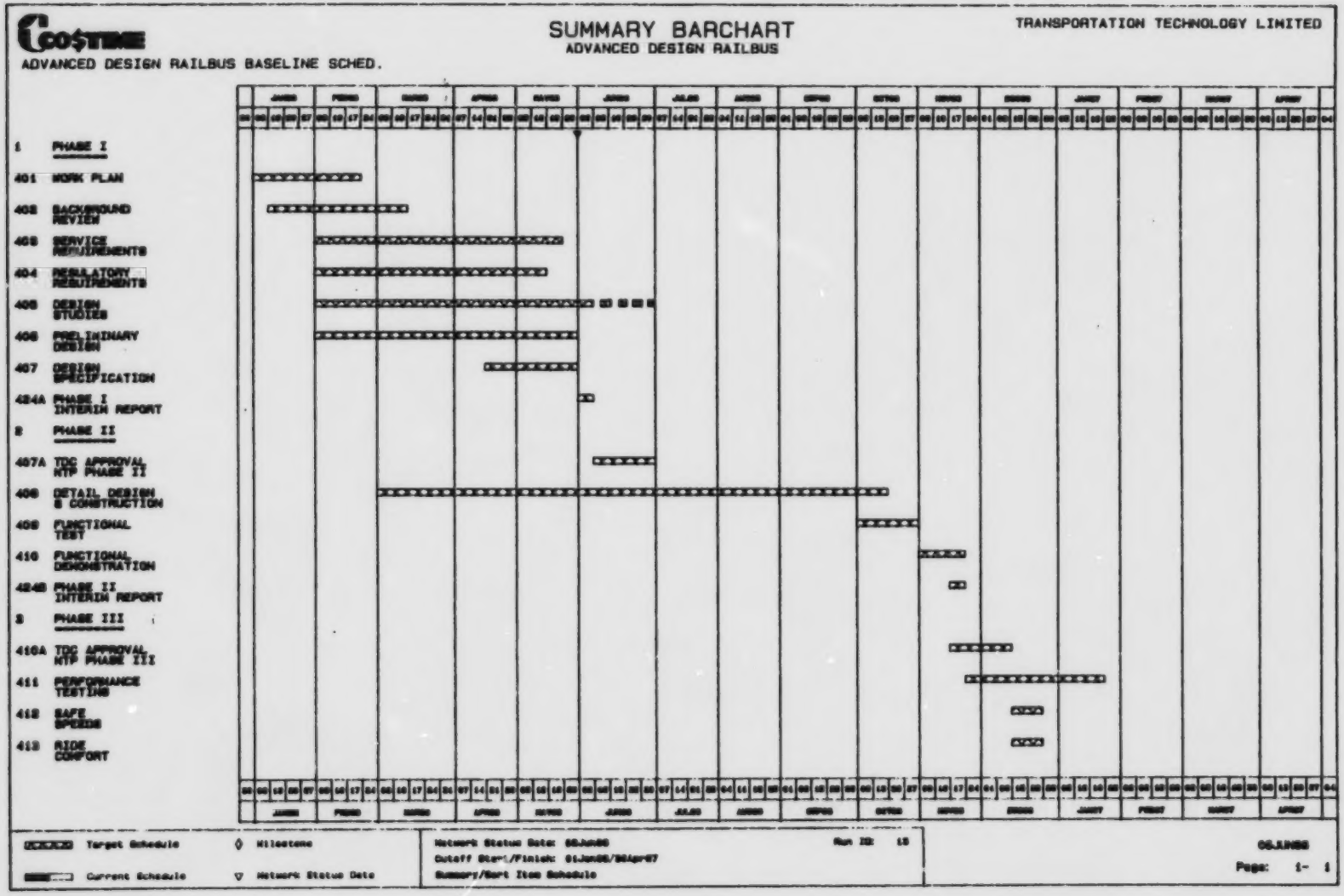


FIGURE 1: PROJECT SCHEDULE

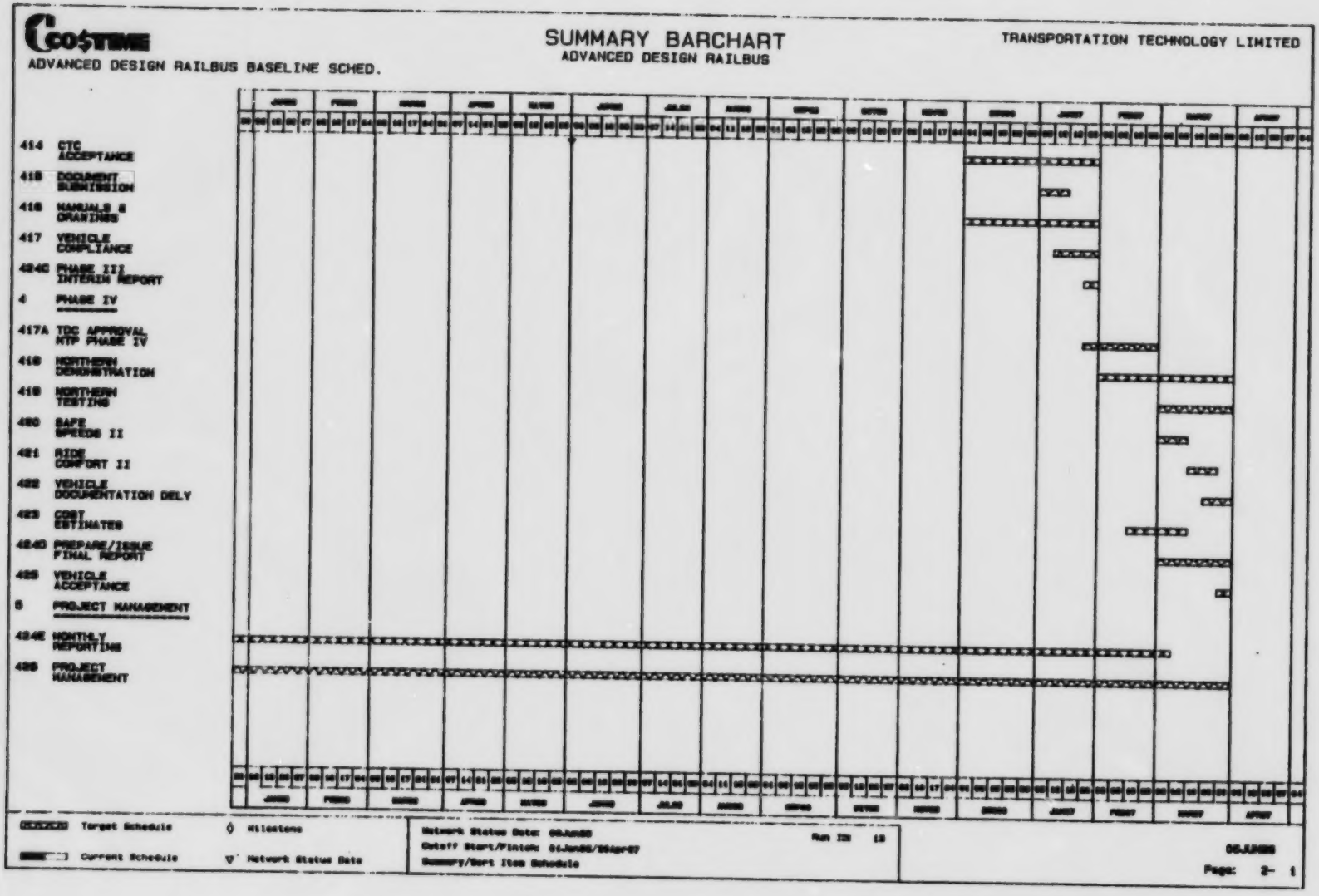


FIGURE 1: PROJECT SCHEDULE (cont'd)

2.0 TECHNOLOGY REVIEW AND ASSESSMENT OF REQUIREMENTS

2.1 BACKGROUND REVIEW

2.1.1 Definition

A railbus is a self-propelled passenger- and light-freight-carrying vehicle combining road coach technology with a rail suspension and guidance system. It may be operated as a single self-contained unit, or as a consist of one "prime mover" with a baggage and light-freight trailer. The ability to operate in a combination of multiple units would be a definite asset. (This definition of the railbus is not to be confused with the relatively heavy and costly conventional diesel rail car.)

2.1.2 Early Projects

The railbus has been in use in one form or another for many years. Since the early 1920s, various vehicles, mostly automobiles and buses, have been modified by the addition of steel flanged wheels for rail use or by the replacement of the entire undercarriage of a rubber-tired vehicle (Ref. 1).

In many cases, these early vehicles were limited in carrying capacity to a maximum of six persons, and in most cases the speed was restricted to a maximum of 30 mph (50 km/h).

For example, a 1934 eight-passenger Packard was converted to rail use in 1936 by the addition of rail wheels attached to the hubs of the original road wheels. Additional snubbers and travel restrictors were included to prevent excess spring travel, and the steering wheel was secured by means of a column lock. Two additional vehicles (Studebakers) were modified by clamping the flanged wheels to the original rubber tiré wheels in order to permit off-rail movement of the vehicles. These units were also fitted with small fore and aft guide-wheel bogies.

As another example, Winnipeg Hydro modified a Wayne School Bus for rail use; this is reported, in a limited way, in a later study for the Manitoba Department of Highways (Ref. 2).

2.1.3 Current Technology

Current railbus technology ranges from a modified, circa-1963 Flyer bus in Manitoba (Ref. 3), to a relatively sophisticated railbus manufactured by British Rail using a modified bus type body. The characteristics of these vehicles are summarised in Table 1 and discussed below:

- Ganz-Mavag of Hungary - This unit is usually a coupled pair and is basically a specialized Ganz-Mavag rail chassis with an Ikarus bus body modified for installation on the rail chassis.

- Fuji Industries of Japan offer a specialized rail chassis with a utilitarian bus-type body.

- COMENG-ANI Corporation of Australia, also supply a specialized rail chassis with a specifically designed body for rail use along the lines of a smaller Budd Diesel Rail Car unit. Two conventional trucks are used.

- MBB of Germany offer a "railbus," but it appears to be more along the lines of a conventional diesel rail car.

- MAK/Krupp also offer units more on the lines of the diesel rail car.

- Czech-Wagonwerk offer a rail car unit. This is similar to the Budd type of diesel rail car but has the advantage of a relatively high mass production and low unit costs due to low labour rates.

- BREL has both in production and in revenue service in the UK a two-axle railbus using a Leyland National bus body mounted on a steel underframe. An example of the Type 141 model of this vehicle is currently under test in Canada as part of the overall Transport Canada railbus evaluation program.

Refer to Table 1 for details of four of these railbus designs.

2.2 SERVICE REQUIREMENTS

2.2.1 Method of Investigation

The methodology selected for Phase I was to rely as much as possible on real-world inputs from Canadian and offshore sources, particularly for determining operating requirements, market desires, regulatory environments, and technology capability. These activities are summarized below:

- Consultation with representatives from VIA Rail, Montreal; CN Rail, Montreal; Canadian Transport Commission, Ottawa; CIGGT, Kingston; and TDC, Montreal.

- Consultation with subcontractors (CANAC) and research into alternative transit/railbus technologies.

- Review of correspondence material between CN Rail, VIA Rail, CTC, and TDC related to the railbus concept that involves service and operating criteria.

- Identification of primary railbus service applications on remote service rail lines from information and statistics provided by VIA Rail and CN Rail, and review of CIGGT reports.

PHYSICAL DATA	BREL/LEYLAND (U.K.)	FUJI HEAVY INDUSTRIES (JAPAN)	COMENG ANI CORPORATION (AUSTRALIA)	GANZ - MAVAG - IKARUS (HUNGARY)
	Type 141 Type 142			
1. Length - Single units (m)	15.3	11.61	16.8	25.4 (double unit)
2. Width - Single units (m)	2.5 2.8	2.6	2.84	2.58
3. Height - Single units (m)	3.97 3.97	3.27	3.84	3.6
4. Wheelbase - Single units -(m)	8.7 8.7	7.0	10.0 (centre of bogie)	8.5 (centre of bogie)
5. Wheel Diameter mm	800	762	760	850
6. Weight Tonnes	28.0	12.5	23.0	32.0 (double unit)
7. Power Plant (all Diesel)	Leyland (horizontal)	Fuji	DDA 6L71 (horizontal)	Cummins (horizontal)
8. HP/KW	217/162	180/135	180/134	340/254
9. Gearbox/Drive	Auto 1 axle	Hydro-mechanical-1 axle (fwd and reverse only)	Auto 1 dble bogie	Hydro-mechanical double bogie fwd & reverse 2 speed
10. Brakes	Air-double tread	Air-double tread	Air-tread or disc	Air - tread
11. Body Construction	Monocoque modules on separate chassis rubber isolators	Monocoque body on separate chassis	Monocoque body on separate chassis	IKARUS Busbody Separate chassis
12. Double Ended	Yes optional	Yes optional	Yes optional	Yes optional
13. Suspension	Flexicoil	Air spring	Rolling ring and coil spring	Steel coil & rubber
14. Trucks	Single axle bogies	Single axle bogies	Double axle bogie	Single axle bogie
15. Doors	High level 2 doors rail platform height	High level 4 doors	High level 4 doors outside sliding	High level - optional extension, 2 door and operator doors.
16. Seating	64	54	58 to 64	86 (double unit)
17. Crush Capacity (standees @ 6 pass./m^2)	104	100	134	160 (double unit)
18. Speed km/h/mph	120/75	70/44	118/73	100/60
19. Grade Capability	4%	N/A	N/A	N/A
20. Curve Radius (m)	75	100	N/A	100
21. Baggage	O'head & internal	O'head	O'head	O'head or special compartment with fewer passengers
22. Multi-consist	Optional	Optional	Optional	Powered Car + Trailer or 2 Powered Cars + trailer.
23. Min. Temp. Operation °C	-40	-40	N/A	-50
24. Toilet/Lav.	Optional	No	Optional	Yes
25. Galley/Snack Service	N/A	N/A	Optional	N/A
26. HVAC	Optional	Optional	Optional	Yes
27. Number in Service	200 +	Approximately 20	40	13

TABLE 1
RAILBUS MANUFACTURERS AND DESIGN DETAILS

N/A - Not available

- o Analysis of data and related experience gained during operation of the WCSS prototype Railbus on the INCO and CN railway lines in Thompson, Manitoba.

- o Discussions with representatives of the Northern communities of Thompson, Thicket Portage, and Pikwitonei, Manitoba.

- o Review of northern remote-service requirements with the Manitoba Department of Highways and Transportation.

The detailed task report is included in this Phase I Summary Report as Attachment A-1 and summarized in the remainder of Section 2.2.

Portions of Attachment A-1 were prepared with assistance from CIGGT, Kingston, under subcontract to TTL.

2.2.2 Summary of Service Requirements

Three potential applications for Railbus service were evident from the study carried out:

- o Regional Service
- o Remote Service
- o Private Line/Special Market

Examination of these applications revealed two somewhat distinct operating requirements, which are summarized in Table 2.

The requirements for range and accessibility were common. In both cases, minimized capital and operating costs were concluded to be essential, given that ridership alone on these lines does not support the total costs of providing the service. In many cases, passenger revenue is not sufficient to justify expenditures required by the existing equipment and operating environment. Even where a pair of vehicles is required for redundancy/reliability, the lighter minimum-change bus technology significantly reduces capital costs.

It should be noted that the opportunity to introduce improved technology would be enhanced greatly in the long run if changes to CTC regulatory requirements are found to be possible. Selected changes would effectively take advantage of the cost-savings potential of new technology. A key element in obtaining these savings lies in the ability to allow a lower buff load than for conventional equipment. This does not take away from the potential for significant savings in operating and capital cost that can be made by using the new technology of the Railbus as a forum for initiating regulatory changes.

The lower regular ridership demand on the Remote/Private Line/ Special Market services can effectively be provided by a very light vehicle with low buff load capability; here emphasis should

Characteristics	Remote/Private Service	Regional Service
Seating Capacity	o Most applications can be serviced by a 40 seat capacity vehicle. o Several applications would benefit from paired vehicle operation for redundancy and reliability, but not required as far as seating capacity is concerned.	o Minimum seating for 80, but most trains would require 120-160 seats with some as high as 200.
Range	o Not less than 1000 km, plus delay/failure-related idle time. o Longer ranges would be of benefit. o Light weight is significant.	o Not less than 1000 km, plus delay related idle time. o Light weight is significant.
Speed	o 50 to 80 kph normal operating speeds with ability to cruise at 100 kph.	o 100 to 115 km/h normal operating speeds, with ability to cruise at 145 km/h on certain routes.
Multiple Unit Operation	o Not required o A single two-vehicle unit meets most requirements.	o MU operation is a definite requirement to meet train capacities. o Consists of more than two vehicles should be able to be coupled /uncoupled, requiring some buff load buff load capability.
Baggage	o Oversized baggage capacity is a must. o Typical baggage may include canoes, snowmobiles, food supplies, oil drums, etc.	o Overhead baggage racks plus underfloor or equivalent storage for larger pieces of luggage.
Food Services	o Require Provision for small galley with hot and cold food services on several lines.	o Coffee/cold drinks and snacks on some vehicles.

TABLE 2: POTENTIAL RAILBUS APPLICATION CHARACTERISTICS

Characteristic	Remote/Private Service	Regional Service
Entry Doors	o Single passenger door only required on most lines. Low level access required. o Crew door at 'B' end beneficial for switching.	o Multiple-passenger entry door access is beneficial. Low level access required. o Same
Handicapped Access	o Provision for access required but incorporation may only be on some vehicles; may be offered as an option.	o Handicapped access likely to be required on sufficient number of vehicles.
Maintenance	o Ideal application for subcontracted maintenance. o Should be very reliable since vehicle recovery can be very costly and difficult. o Cannot require servicing in specialized maintenance facility. Such facilities are not located near most remote services.	o Since Regional Markets are close to existing maintenance facilities and since quantities are relatively large, use of existing railway maintenance facilities may be best although subcontracting of cleaning may be advantageous.
Estimated Market	20 single vehicles including trailers, plus an unknown speciality market.	Equivalent to 60-80 single vehicles. [Note VIA estimates range as high as 100-140 units Ref. 6]

TABLE 2: POTENTIAL RAILBUS APPLICATION CHARACTERISTICS (Cont'd)

be placed on inexpensive but proven automotive bus technology, and an existing structure requiring only minimum modifications.

If all present regulatory standards are maintained without change, the requirements for Regional Service, where multiple units and higher speeds are required, might still be effectively provided by lightweight rail vehicle technology, with the buff load capability provided by a reinforced bus structure or independent subframe structure.

Arguments for utilizing a single type of Railbus vehicle to operate on all services in order to provide commonality of spare parts and a better bargaining position when purchasing equipment are valid when both types of service operate from a central hub. In remote/private services, however, these factors do not apply to any extent, and any gains made by increasing the order quantity of the more costly regional railbus would be outweighed by the savings in capital and operating costs of a minimum change automotive-based Railbus.

With respect to acceptance of this type of new Railbus technology, a survey of customer acceptance would be required. In the remote service applications, experience with the testing of the WCSS Railbus has shown excellent public acceptance, and it is anticipated that a trial passenger service run would show positive feedback. In the Regional markets, however, comparisons with the highway coach may make acceptance of Railbus technology less than desired. More attention to comfort and service frequency may be required in these markets.

Baggage capacity requirements for remote services should be verified by a survey of present usage and anticipated potential requirements.

2.3 REGULATORY REQUIREMENTS

The requirements contained in this section outline the current status of regulations to be addressed prior to the acceptance of the Railbus vehicle by the CTC and Canadian Railway regulatory authorities, based on review with these bodies and VIA.

2.3.1 Safety

UCOR Regulation No. O-8, Sections 11-1 and 11-2, specifies that motive power passenger vehicles must be equipped with a full set of flagging signals stored in a suitable container. The flagging kit must include:

- a red flag on a staff;
- a white light;
- torpedoes; and
- fuses.

CTC General Order No. O-21 specifies that the vehicle be equipped with a suitable fire extinguisher(s) of adequate capacity, and be placed in a convenient and accessible location where it may be readily available.

CN Rail requires that the vehicle be equipped with the following emergency supplies:

- stretcher;
- first aid kit;

- o shovel;
- o pike;
- o crow-bar; and
- o switch broom.

CTC General Order No. 0-27 specifies that a coach used in revenue passenger service must be equipped with emergency tools consisting of:

- o one 2.7 kg sledge hammer (6 lb);
- o one 2.0 kg axe (4½ lb); and
- o a saw.

The emergency tool cabinet must be located in the main body of a revenue passenger coach and be easily accessible, avoiding locations behind doors or other obstructions. The cabinet must have 1/8" thick glass in its door.

CN Rail recommends that passenger vehicles for revenue service to remote areas be equipped with a suitable self-contained auxiliary emergency heater.

CN Rail also suggests that the vehicle be equipped with rerailers and suitable equipment for use in rerailing the vehicle in a self-contained manner.

2.3.2 Lighting

CTC General Order No. 0-14 specifies that trains must be equipped with headlights having a sufficient illumination capacity to enable a person in the leading cab to see a dark object the size of an adult standing at a distance of at least 244 m (800 feet) in a direct line ahead of the train.

The operation and control of the headlights must be through a dimmer switch located and installed in a safe and convenient manner. UCOR Rule 178 specifies that under conditions requiring a vehicle to run backward at night, a white light must be displayed on the leading end.

CN Rail locomotives use two 200 watt, 30 volts, PAR 56 lamps, each with a rated output of 260,000 candle power. The dimming switch may be adjusted to decrease such light intensity to the equivalent of two 50 watt lamps.

CN Rail specifies that spare parts (i.e., lamps and power fuses) are to be stored on vehicles or trains for emergency use.

CTC General Order No. 12-38525 specifies that by April of 1986 all lead locomotives must have ditch lights that meet CTC specifications requiring two 350 watt lamps, each directed at the centre line of the track, to illuminate the track 400 feet ahead of such locomotive.

CTC General Order No. O-14 specifies that trains operating between sunset and sunrise must have cab lights in lead locomotives that provide sufficient illumination of dash panel gauges to enable an engineman to take necessary and accurate readings from normal and unusual positions in the cab. The lights are to be located and installed to allow lighting of only those parts requiring illumination. Additional cab lights are required to enable crews to easily and accurately read train orders and timetables. The lights are to be so installed that they may be readily switched off when not required.

CN Rail also requires and provides in their own vehicles indicator lights inside a locomotive cab to enable the engineman to verify the operation of outside lights such as classification, marker, and headlights.

CTC General Order No. O-14 specifies that the vehicle is to be equipped with electrically lighted classification and marker lamps. White and green classification lights must be located at the front, with red and green marker lights at the rear. CN Rail uses 30 watt lamps for classification and marker lights. The required lights on each side and each end of the vehicle must be independently controlled (electrically switched).

CN Rail specifies no other lights except those required for travel and identification may be illuminated during operation. The front and rear clearance lights fitted to a normal highway bus are to be omitted from the RailBus vehicle.

CN Rail requires lead locomotives to be fitted with a forward facing number (two digits satisfactory, 90 mm high) and be lighted during operation. Three 30 watt lamps are used by CN Rail to backlight such numbers.

Emergency lighting must be provided in the vestibule area and throughout aisles and passageways to adequately illuminate the vehicle interior for safe exit during an emergency. The emergency lighting must illuminate automatically should the main power unit fail. The power source would be from the main batteries.

2.3.3 Flags

UCOR Rules 20 and 21 specify that motive power units must be equipped to display two green or white flags on the leading end of such unit, except that white flags need not be displayed in CTC territory.

2.3.4 Bell

The Canadian Railway Act and CTC General Order No. O-25 require the use of a 30 lb bell. No loudness characteristics are specified. The bell is to be equipped with an air bell-ringer.

2.3.5 Horn

CTC General Order No. O-25 specifies that motive power units must be equipped with horns tuned in chords of not less than three tones. The horns must be located as to make the sound practically omni-directional. CN Rail requires that their locomotives be equipped with a horn having an air intensity of 114 dBA to be heard at a distance of 30 m (100 ft.) forward of the direction of travel.

Note: Recent experience during winter snow conditions with the WCSS vehicle has shown that the horn's location is important to minimize the effect of weather on its performance; in addition, tests showed that typical automotive horns are not loud enough to be heard from the desired distance by the driver of a car with its engine and radio on, thus requiring a locomotive style horn.

2.3.6 Pilot

CTC General Order No. O-10 specifies that motive power units must be equipped with a pilot (flanger) that:

- is located at the front of the leading end;
- has a minimum height above the rail of not less than 76 mm (3.0 in) and a maximum of not more than 152 mm (6.0 in); and
- is securely attached and braced.

The CTC General Order also requires handholds, footrests, and two pilot steps to be installed at the right and left sides of the pilot. The steps must be constructed of sufficient width and depth for an employee to stand on.

If the vehicle design is capable of bi-directional operation, such a unit must be equipped with a pilot at each end.

2.3.7 Air Reservoirs

CTC General Order No. O-21 cites various regulations to the design, construction, and maintenance of the air reservoir(s). The regulations outline identification, pressure gauges, safety valves, drain valve, along with setting and inspection procedures.

2.3.8 Brakes

CTC General Order No. O-10 specifies that passenger trains must have air brakes and at no time may be run with less than 85% of such brakes operative. The Railway Act requires that the system of brakes must be continuous and instantaneous in action.

CN Rail requires air hoses to be attached to the front and rear of the Railbus vehicle, enabling a locomotive to pressurize and hold-off the service and emergency brakes should the vehicle be towed or pushed. Alternatively, a hand-operated 'wind-off' mechanism would be required at the wheel brake assemblies.

Design considerations which would avoid the brake shoes freezing on should be made with respect to equipment selection and suitability for cold weather conditions.

CN Rail requires that braking rates are to be adjustable in order to avoid wheel flats. All new locomotives are being equipped with a wheel-skid and slippage detection device that provides an audible or visual alarm in the lead locomotive cab, to detect any wheel skid or slippage on the entire consist.

In the event of a railbus recovery with a train or locomotive coupled-up, minimum brake pipe pressure required to hold-off the brake shoes would be 50 psi (if the brakes are spring-on, air-off).

2.3.9 Fuel Tank

CTC General Order No. O-21 specifies that motive power units be equipped with a fuel tank(s) which provides a suitable liquid level gauge(s) so located that the fuel level can be determined when the tank is being filled. The gauge must be protected against accidental breakage where loss of fuel would be incurred. The tank(s) is to be provided with a vent which leads to the outside of the vehicle, but does not discharge on the roof.

2.3.10 Engine

CTC General Order No. O-21 requires that motive power units be protected from overspeeding and overheating by use of suitable warning, indicating, or governing devices. The lead cab must be equipped with speed indicators which are easily read and continuously illuminated.

Redundancy in equipment selection such as alternators and emergency batteries are suggested by CN Rail for incorporation in newer locomotives.

2.3.11 Accident and Fire Prevention

CTC General Order No. O-28 specifies that a motive power unit's exhaust gases be directed away from the track bed, in view of their potential for fire hazards. This regulation also specifies that internal combustion engines of motive power units, if not equipped with an exhaust driven centrifugal turbo-charger, must have installed integral with the exhaust gas system a spark-arresting device approved by the Director of Operations.

CTC General Order No. O-21 specifies that exposed moving parts of machinery must be provided with suitable guards and safety devices. Jumper cables and hose connections at the ends of motive power equipment must not be allowed to hang with one end free and must be so located and guarded as to prevent accidental entanglement.

The CTC requires that passenger sections, end walls, and floor assemblies must meet specified resistance to fire penetration. Test methods shall meet VIA acceptance standards.

2.3.12 Wheel Sanders

CTC General Order No. O-21 specifies that a suitable sanding apparatus be located on self-propelled motive power equipment and arranged to deliver sand on the rails in front of the driving wheels when required by operational or track conditions.

No part of appliances or power equipment (except the wheels), flexible non-metallic parts or pipe extensions may be located less than 64 mm (2.5 in) above the top of the rails.

2.3.13 Wheels

CTC General Order No. O-19 specifies that motive power units are to have their wheels securely fitted to the axles. The diameter of wheels on the same axle must not vary more than 2.4 mm (3/32 inch).

2.3.14 Couplers

CTC General Order No. O-10 specifies that motive power units must be equipped with automatic-type couplers at the front and rear. Coupler centre height is to be maintained at the prescribed nominal height of 876 mm (34.5 in), 800 mm (31.5 in.) minimum and 890 mm (35 in) maximum.

CN Rail requirements indicate that, as a minimum, a suitably designed draw-bar attachment may be substituted for couplers providing the RailBus vehicle can be securely coupled to a standard locomotive. The attachments must be adaptable to either end of the vehicle and stored in an easily accessible place.

CN Rail also requires a tow cable or chain to be stored on the vehicle for emergency use.

2.3.15 Deadman Control

CTC General Order No. O-21 specifies that a deadman control be installed that, should the engineman become incapacitated, will automatically apply not less than a full service application of the vehicle brakes and reduce the transmission of power to the driving axles in order to bring a train to a complete stop as expeditiously as possible. The braking rate applied must not allow the wheels to lock and skid.

2.3.16 Windows

CTC General Order No. '1982-9 Rail' specifies that motive power units be fitted with certified CTC shatterproof glazing material in windows and cab door(s).

CTC General Order No.O-21 specifies that front windows be equipped with efficient wipers, sun visors, and defrosting devices where necessary.

2.3.17 Seat Accommodation For Train Crew

CTC General Order No. O-18 specifies that motive power units provide seating accommodations for the train crew and that the engineman's seat must have a back and window arm-rest.

For the Railbus vehicle operation in remote areas, CN Rail requires that a protective barrier be added which would isolate the operator from the passengers, and also collision posts be installed around the operator's area to protect such operator during a collision.

CTC General Order No. O-8, Section 13, specifies that the train crew is to be comprised of at least an engineman and a conductor (or attendant). CN Rail further requires that a Railbus vehicle operator be CN A-book qualified and trained in railway safety and emergency procedures.

2.3.18 Communication Facilities

CN Rail specifies that motive power units be equipped with a permanently mounted two-way FM radio capable of communications with the train dispatcher and other railway employees. CN Rail also suggested that the vehicle be equipped, when operating in remote services, with a two-way base station radio suitable for emergency communications to a local mobile operator.

2.3.19 Sanitation Facilities

CTC General Order No. R-O-37 specifies that new motive power units be equipped with suitable toilet facilities. Such facilities installed must be of a design and type so that human waste will

not be dumped onto the roadbed and that it is suitable for year-round operation. The facility is also to be ventilated away from the vehicle's interior.

The order also specifies that motive power units be equipped with a portable water supply (chilled) and single-service cups contained in a suitable permanently mounted dispenser.

Hand cleaning and drying facilities and materials must also be provided.

2.4 DISCUSSION OF THE REGULATIONS

CTC regulations state that requests may be made for motive power units of untried types such as Railbus vehicles to be relieved of some rules and regulatory requirements, providing a full complement of suitable safety appliances are in their proper place as specified by CTC General Order No. O-10, Section 514.

Review of the UCOR and other requirements suggests some relief from the rulings be requested from the CTC for operation of the Railbus vehicle. At present, CN Rail is requesting that operational and technical items stated by the UCOR and CTC requirements be provided for in the design of the vehicle and certain specific recommendations have been made by CN (See Attachment A-4). In discussion with Canadian Railway authorities, some CTC regulations may be inappropriate for incorporation on a Railbus vehicle.

In view of standard features and safety features presently installed on conventional motive power units for rail use, as regulated by the CTC, Table 3 outlines the CTC technical, operational, and regulatory requirements that TTL is proposing be waived or modified in the design of an Advanced Canadian Railbus vehicle.

With respect to the subject of buff loads it was concluded at the previously referenced review meeting (A-4) that some level of buff load capability is required, but that blindly following AAR regulations is not appropriate.

ITEM	REGULATORY REQUIREMENTS	PROPOSAL TO CTC
Sill steps, hand-rails, ladders and running boards	CTC General Order No. O-10, requiring the installation of such items.	Request relief from requirement for the following reasons: o Vehicle will not be coupled to other vehicles while in revenue service. There is no need for a crewman being on any of the required items, or to walk to the rear of the vehicle from the outside; o A type of fold down step at entrance doors would be fitted to vehicle for passenger and crew convenience.
Pilot steps	CTC General Order No. O-10, requiring the installation of a pilot with footrests and handholds on each side.	The pilot would be installed as required, but request relief from the installation of footrests and handholds. A crew member would not be required to be on the footrests or to cross over to the other side of the vehicle as with conventional rail equipment involved in switching operations.
Automatic rail-type couplers at front and rear, and uncoupling levers.	CTC General Order No. O-10, requiring the installation of standard railway couplers.	Request a modification in the application of this requirement. CN Rail has suggested that a suitable drawbar attachment would be acceptable. The Railbus vehicle would not be involved in conventional railway shunting operations. A suitable drawbar would be used only for a recovery of a failed vehicle. It would also be lighter; therefore, lighter coupling facilities would be satisfactory.
Flags	UCOR rules 20 and 21 requiring the use of flags.	Display just the required lights. In non-CTC territory, white lights and white flags on the leading end need not be displayed. TTL proposes to display white lights when vehicle is in non-CTC territory and green lights as required.
Headlights	CTC General Order No. O-14, requiring the use of headlights to illuminate a range of 800 feet. UCOR rules 17, 17A, 17B, 17C, and 17D prescribe the use of headlights.	TTL originally proposed a relaxation of this requirement to 600 feet since the Railbus vehicle may be stopped within very short distances at moderate speeds, due to its relatively high braking rate design and the US Locomotive Standards are 200,000 candle power for an illumination range of 600 feet. However, based on review of the CN Recommendations (A-4), the range of 800 ft will be complied with.

TABLE 3: TTL PROPOSED WAIVERS FROM CERTAIN CTC AND REGULATORY REQUIREMENTS FOR DESIGN OF ADVANCED CANADIAN RAILBUS VEHICLE

ITEM	REGULATORY REQUIREMENTS	PROPOSAL TO CTC
Ditch lights	CTC General Order No. 12-38525, requiring the use of two 300 watt ditch lights.	TTL proposes a relaxation of this requirement or, as a maximum, two - 100 watt lights. CP Rail initiated the use of ditch lights with two 300 watt lights and CN Rail are now using two 350 watt lights. As mentioned, a Railbus vehicle would be able to stop within very short distances, should a potential obstruction appear.
Bell	Section 241 of the Railway Act and CTC General Order No. O-25 require the use of a 30 lb bell. UCOR rule 30 prescribes the use of the bell.	TTL proposes to replace the 30 lb bell with a smaller electronic or electro-mechanical device in order to comply with UCOR rule 30. The 30 lb bell was originally intended to be used by an engineman on a steam locomotive with poor visibility when approaching nearby personnel. Design of the Railbus vehicle would give the operator a very clear view of nearby personnel.
Horn	CTC General Order No. O-25 requires the use of a three-tone horn of 114 dBA to be heard within an arc of 45° on each side of the lead motive unit, at a distance of 30 m. UCOR rule 14 prescribes the use of whistle signals.	The three-tone horn was originally created to have an air intensity of 114 dBA and to sound like the whistle of a steam locomotive. No animals make a call of the same type and therefore were not attracted to the tracks by this noise. Today, on many locomotives, one of the three chords is turned backwards to call attention to brakemen or flagmen checking a train or a conductor at the rear of a train. TTL originally proposed to use a two-tone horn, in order to comply with UCOR rule 14, with a sound level of 96 dBA heard at 30 m. Signalling to crew members would not have to be done with a horn in the case of a Railbus vehicle. Based on a review of CN recommendations (A-4), TTL intend to comply with a 3-tone locomotive type horn.
Exhaust Gases	CTC General Order No. O-28 requires the adoption of a spark-arresting system.	TTL proposes a waiver, from this requirement since the turbo-charged engine does not emit dangerous sparks that could cause a fire hazard along railway trackage.
Protective Operator's Cab	CN Rail requests a fully enclosed operator's cab.	TTL presently proposes to have a partition between the operating cab and the passenger area for the pre-production vehicle.

TABLE 3: TTL PROPOSED WAIVERS FROM CERTAIN CTC AND REGULATORY REQUIREMENTS FOR DESIGN OF ADVANCED CANADIAN RAILBUS VEHICLE (CONT'D)

ITEM	REGULATORY REQUIREMENTS	PROPOSAL TO CTC
Windows and escape hatches	CTC General Order No. 1982-9 Rail specifies that windows be CTC-certified shatterproof glazing material. Some windows must allow for emergency escape.	TTL proposes to abide by the CTC General Order with the addition of two roof escape hatches on each vehicle, and glazing that meets CTC and CMVSS road safety standards. All major side windows on the Railbus are operable.
Fuel tanks	CTC General Order No. O-21 requires that the fuel tank of motive power be equipped with a liquid level gauge in order to determine the fuel level when a tank is being filled.	The sight-glass was originally created: o since gauges could not be relied upon at that time, and o to avoid fuel spillage when fueling. TTL proposes to fit the vehicle with an auto-filling and spillage - avoiding device that requires a fuel pump to stop when the tank is full, and to ensure an accurate gauge is adopted so that the vehicle operator can determine fuel level.
Train Crew	CTC and CN Rail require a two-member train crew.	One A-Book qualified engineman is all that is needed to safely operate a Railbus vehicle. In England, a one-person crew is used, with an attendant added only when passenger levels are high or when two or more vehicles are coupled together.
Crash Posts (Collision Posts) and Buff Loads	CTC and CN Rail require the installation of crash posts. CN Recommend 400,000 lb buff load (A-4)	TTL proposes to be relieved of this requirement in the design of the preproduction prototype Railbus vehicle, but will investigate integration into production vehicles of crash posts and an appropriate level of buff load capability.
Fire Resistance	CTC requires that passenger sections, end walls, and floor assemblies conform to VIA Rail acceptance standards.	TTL proposes these standards be waived as such, but to conform to safety and fire standards set for highway coach construction.

TABLE 3: TTL PROPOSED WAIVERS FROM CERTAIN CTC AND REGULATORY REQUIREMENTS FOR DESIGN OF ADVANCED CANADIAN RAILBUS VEHICLE (CONT'D)

3.0 DESIGN STUDIES

In this section the work carried out to investigate the various areas of interest, such as vehicle dynamics, is described. In each area the analysis and conclusions are reviewed which led to the selected preliminary design described in Section 4.0.

3.1 DYNAMIC ANALYSIS AND CURVING PERFORMANCE

The preliminary design concept assumes that the baseline MCI 102A2 coach undergoes very little in the way of structural modification. The same holds true for the proven rail components, consisting of wheels, axles, bearings, and final drive gearbox. Therefore, the suspension system has to not only provide the desired performance but meet with all the constraints of a limited installation envelope and the geometry of the original vehicle's driveline and suspension pick-up points. In practice, this will be achieved by means of a fabricated steel subframe (the equivalent of a truck), which has mounting points for the conventional rail hardware, and which interfaces correctly with the coach airbag mountings and locating links.

The suspension will consist of a primary spring of rubber shear pads arranged in chevron pattern between the axle bearing housings and subframe, and airbags providing a soft secondary suspension between the subframe and coach.

3.1.1 Purpose of the Analysis

The purpose of the analysis was to investigate and optimise the trade-off between suspension components including:

- Primary suspension: a choice of chevrons with various characteristics;
- Traction rods: a range of possible connection points (changing the effective lateral and longitudinal stiffness);
- Longitudinal links: a range of possible connection points (changing the effective yaw stiffness of the body); and
- Cross-bracing: option of adding cross-bracing (either conventional mechanical bracing between subframes or hydro-pneumatic units).

The performance analysis will be used to design the railbus to meet stability requirements while optimizing curving performance and the body natural frequencies (related to ride). During final design stability and curving would be checked in both directions because of the uneven weight distribution.

3.1.2 Optimization Criteria

The established criteria for lateral stability is a minimum modal damping of 10% up to the maximum operating velocity of 26.8 m/s (60 mph) and a critical speed of over 33.5 m/s (75 mph). In order to optimize curving performance, the angle of attack and wear indices will be minimized. The target body frequencies for good ride characteristics are shown in Table 4. By designing as close to these values as possible while maintaining stability, the ride quality will be optimized.

	EMPTY	LOADED
1. Vertical	1.00	1.00
2. Upper Centre Roll	1.15	1.00
3. Yaw	1.15	1.00
4. Lower Centre Roll	.60	.50

TABLE 4: TARGET BODY FREQUENCIES (Hz)

3.1.3 Optimization Strategy

The K_S - K_B diagrams (Figure 2) illustrate the compromise between stability and curving performance. K_S is the interaxle shear stiffness of the vehicle; and K_B is the interaxle bending stiffness. Without cross-bracing the vehicle operates under the limit line ($K_S = K_B/a^2$ where "a" is half of the wheelbase).

Figure 2a shows the critical velocity contour over a range of K_S and K_B for a two-axle vehicle similar to the railbus.
Figures 2b and 2c show the leading axle angle of attack for a 300 m and 1000 m curve radius, respectively. It can be seen that curving performance is primarily a function of K_B, the interaxle bending stiffness. Curving improves as K_B is reduced.
Figure 2a also shows that to maintain a given level of stability while minimizing K_B, the optimum operation point is close to or above the limit line.

Several strategies were developed based on these diagrams:

o Strategies for Design Options without Cross-Bracing

- keep operating point close to limit line (K_S limit = K_B/a^2, target K_S 90% of K_S limit)
- minimize K_B while maintaining stability requirements

o Strategies for Design Options with Cross-Bracing

Cross-bracing between the subframes allows the vehicle to operate above the limit line. It increases the shear stiffness and has no effect on the bending stiffness.

- use cross-bracing to shift operating point to a more favourable location (same as A above), if design options without cross-bracing are not sufficient to do so; and

- use cross-bracing to provide stiffness between the subframes in order to allow reduced stiffnesses between subframes and body (this will reduce the body natural frequencies and improve ride).

3.1.4 The Railbus Model (Stability & Curving)

The railbus is modelled with 9 elements and 45 degrees of freedom. Table 5 describes the elements, and lists each element's degrees of freedom and centre of gravity position. The coordinate system follows the right hand rule with the origin at the rear of the bus along the centre line at the top of rail. "X" is positive towards the front of the bus, "Y" is positive to the right, and "Z" is positive down. Table 6 describes the suspension elements modelled in the analysis. Figure 3 shows a schematic of the model.

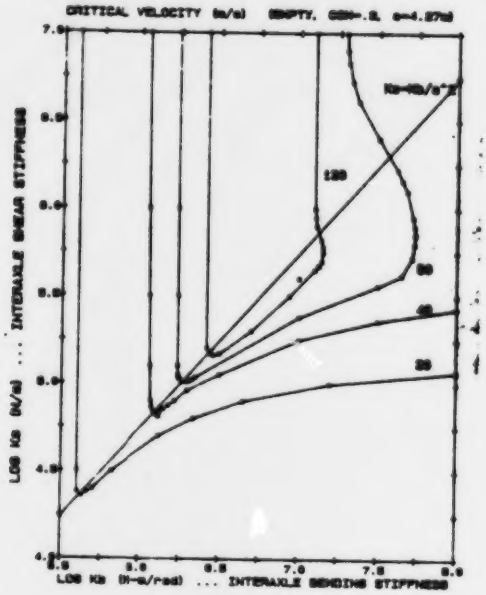
ELEMENT	DEGREES OF FREEDOM						CG POSITION (M)		
	lat	long	vert	roll	pitch	yaw	X	Y	Z
1. leading axle	13	1	0	0	0	3	10.516	.114	-.380
2. leading subframe	14	5	0	7	19	6	10.587	.345	-.488
3. body	8	9	0	11	21	10	6.023	.0	-1.326
4. trailing axle	12	2	0	0	0	4	2.642	.114	-.380
5. trailing subframe	15	16	0	18	20	17	2.816	.179	-.469
6. leading r. tr. rod	22	23	24	25	26	27	10.894	.225	-.711
7. leading l. tr. rod	28	29	30	31	32	33	10.894	-.225	-.711
8. trailing r. tr. rod	34	35	36	37	38	39	2.222	.428	-.875
9. trailing l. tr. rod	40	41	42	43	44	45	2.222	-.428	-.875

TABLE 5: THE RAILBUS MODEL - ELEMENT DATA

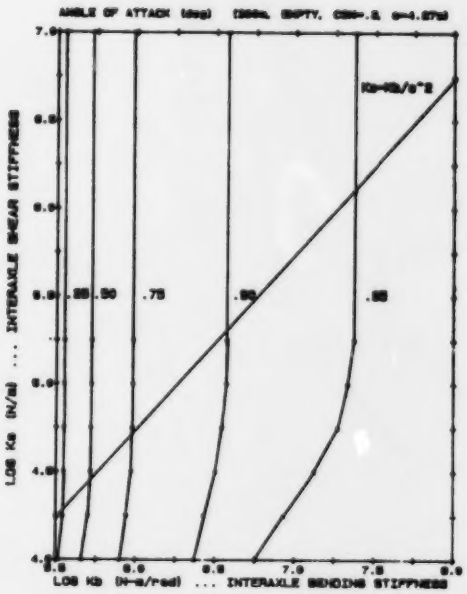
SUSPENSION ELEMENT	DIRECTION OF STIFFNESS						#	POSITIONS
	Long	Lat	Vert	Roll	Pitch	Yaw		
Chevron	X	X	X				4	leading axle - subframe right left trailing axle - subframe right left
Longitudinal link	X						4	leading subframe - body right left trailing subframe - body right left
Leading airbag			X				1	leading subframe - body
Trailing airbags			X				2	trailing subframe - body right left
Antiroll bar				X			1	trailing subframe - body
Traction rod bushing	X	X	X	X		X	8	leading right frame end body end left frame end body end trailing right frame end body end trailing left frame end body end
Damper		X	X				2	leading subframe - body trailing subframe - body
Frame brace	X (directed)	X					2	leading - trailing subframe

TABLE 6: THE RAILBUS MODEL - SPRING DATA

A.



B.



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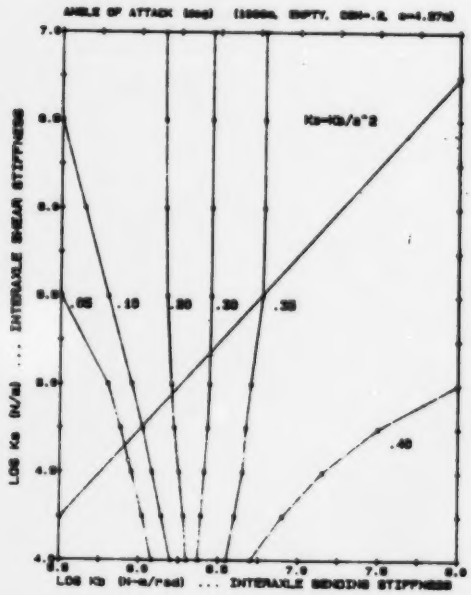


FIGURE 2: K_S - K_B DIAGRAMS - CRITICAL VELOCITY AND ANGLE OF ATTACK

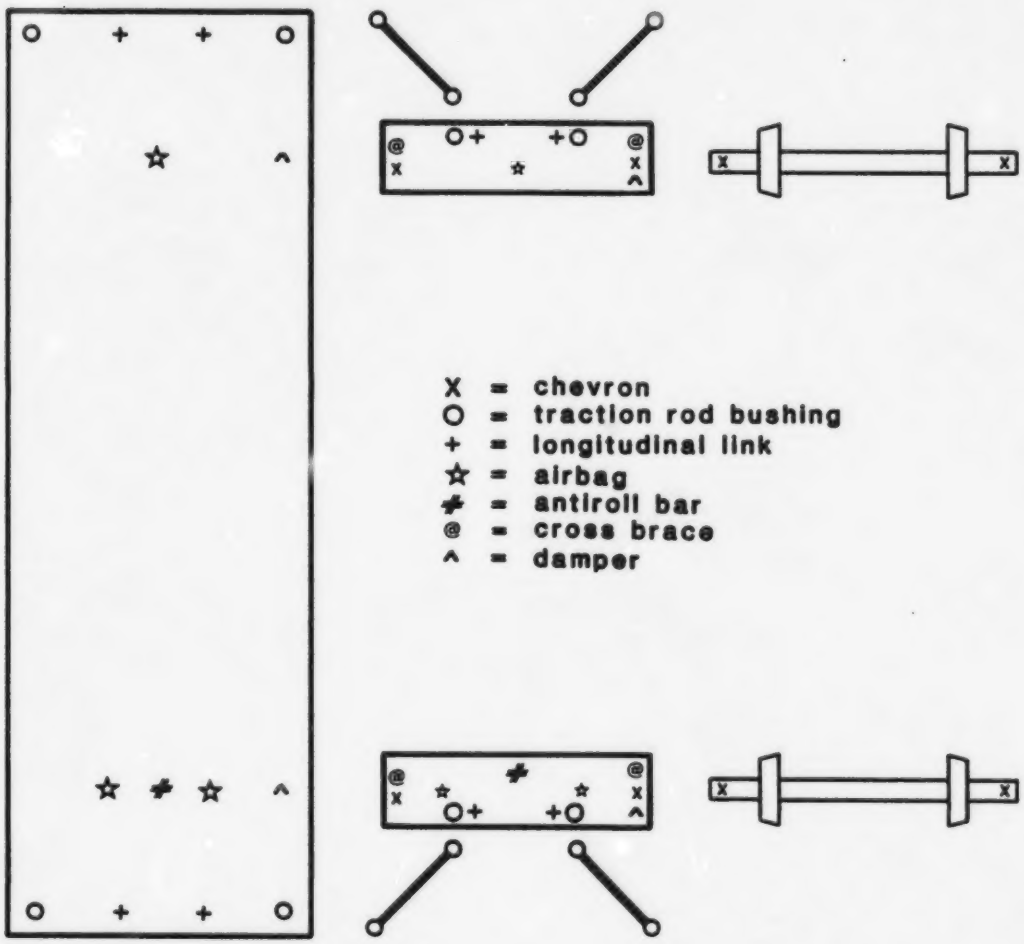


FIGURE 3: RAILBUS MODEL

3.1.5 Preliminary Analysis Results For Design Without Cross-Bracing

The effect of conicity and creep on stability was first investigated in order to determine the worst conditions. From this study, the worst condition considered is 0.2 conicity (which represents a worn wheel) and 100% creep. These parameters were used for the runs comparing various designs.

In the design case without cross-bracing, the options available to alter the performance of the vehicle are the choice of the chevron and the positioning of the traction rods and longitudinal links.

Figure 4 shows the results for two designs which contain different chevrons. The graphs on the left hand side are for Design A, which has a chevron stiffness of 2.1E6 N/m laterally and 5.9E6 N/m longitudinally. The graphs on the right hand side are the equivalent plots for Design B which has a stiffer chevron of 4.0E6 N/m laterally and 1.92E7 N/m longitudinally.

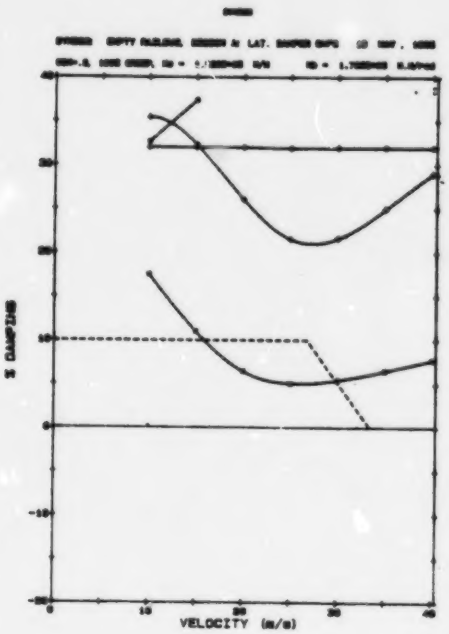
The stiffer primary suspension of Design B has increased both the shear stiffness, K_S, and the bending stiffness, K_B, by 30%. It was shown in Section 3.1.3 that curving improves as K_B is reduced, and stability generally increases as K_S and K_B are increased. As expected, Design B has better predicted stability and Design A has better predicted curving performance.

Design A does not meet the stability requirements; therefore, it is eliminated as a possible design. Design B exceeds the stability requirements.

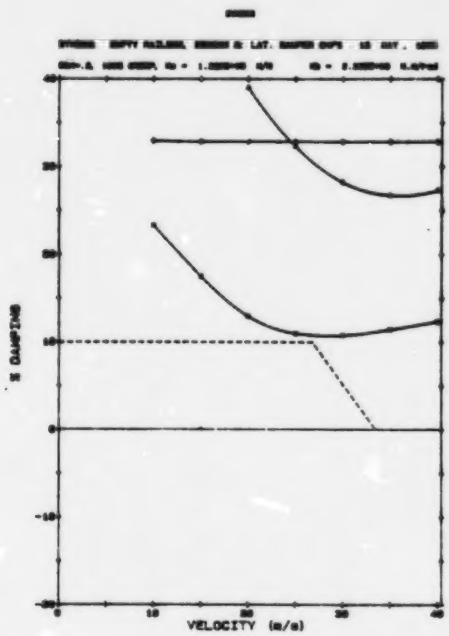
The case where half of the lateral dampers have failed was investigated by halving the damping contributed by the lateral dampers positioned between the subframes and the body. The modal damping is reduced considerably; therefore, it would be necessary for a vehicle with this design to have adequate preventive maintenance to ensure the viability of the dampers. With modal damping of 5%, as predicted for this case when half of the dampers fail, one would expect the stability of the vehicle to deteriorate slightly.

All of the other off-the-shelf chevrons that are available have a higher longitudinal stiffness and a lower lateral stiffness than the chevrons utilized in Design B. The higher longitudinal stiffness would increase the bending stiffness of the vehicle and would therefore deteriorate the curving performance further. For this reason they were not considered.

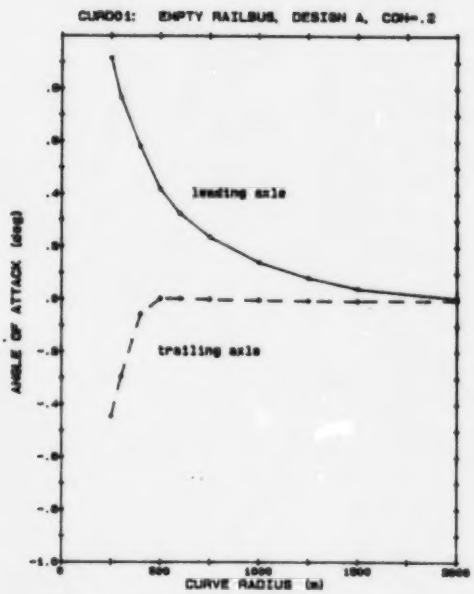
In Design A and B, the traction rods were positioned at the maximum angles, which can be physically achieved in the bus, in



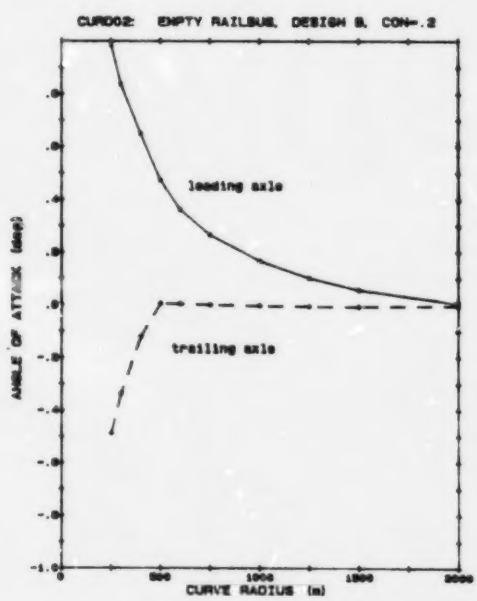
A. DESIGN A, STABILITY



B. DESIGN B, STABILITY



C. DESIGN A, CURVING



D. DESIGN B, CURVING

FIGURE 4: COMPARISON OF DESIGNS A AND B

order to maximize the effective lateral stiffness and minimize the longitudinal stiffness. This arrangement gives the lowest bending stiffness and thus the best curving performance.

Two additional designs were analyzed which were identical to Design B except that the longitudinal links between the subframes and the body were positioned lower and closer to the centreline of the vehicle. Curving performance was improved but stability was reduced to an unacceptable level.

Design B is therefore the optimum preliminary design without cross-bracing.

3.1.6 Analysis of Designs With Cross-Bracing

Two diagonal braces were added to the design between the subframes at the same approximate positions as the bearing housings. These braces provide shear stiffness without contributing to the bending stiffness. Figure 5 shows stability and curving results for a cross-braced design using the softest available chevrons, the traction rods positioned longitudinally along the vehicle centreline, and the longitudinal links at positions 0.5 m from the centreline. Both the stability and the curving performance are superior to the optimum preliminary design without cross-bracing. Based on a preliminary comparison of modal frequencies, the ride would also be superior. A complete frequency analysis will be done in the detailed design.

For this design, the shear stiffness has been increased to fifty times the value in Design B, and the bending stiffness has been decreased to 70% of the Design B value.

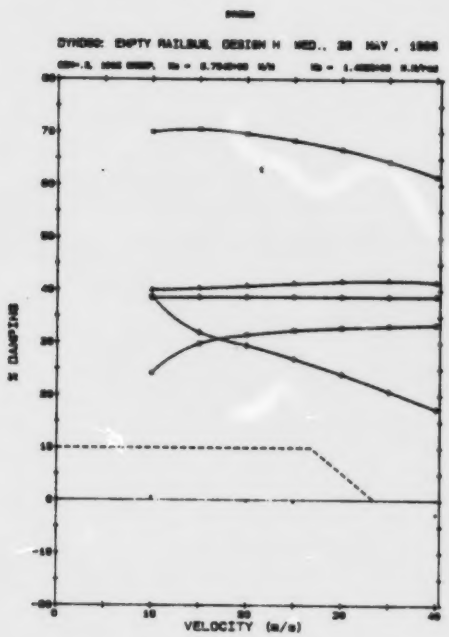
In the detailed design, the cross-braced design will be optimized.

Mechanical and hydro-pneumatic unit cross-bracing will be investigated with various primary chevrons, and positioning of the longitudinal links and traction rods.

Hydro-pneumatic cross-bracing has the following advantages over mechanical bracing:

- the range of obtainable stiffness and damping characteristics is much wider than mechanical bracing;
- the flexibility of attachment and routing of the lines enable the units to be used where mechanical bracing would be impractical.

These characteristics may be useful in the railbus design.



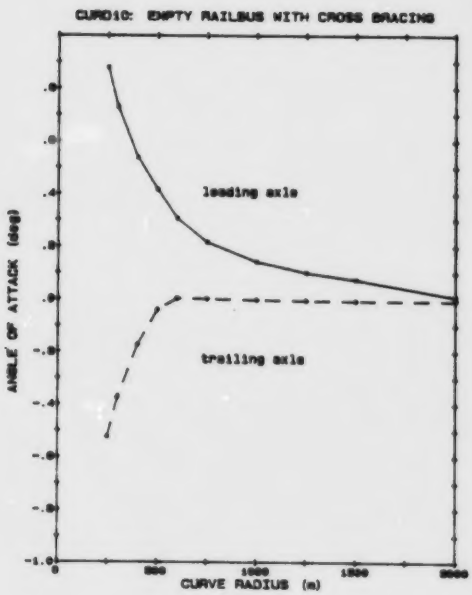


FIGURE 5: CROSS-BRACED DESIGN STABILITY AND CURVING

3.2 WEIGHT AND BALANCE

During the conversion, the centre of gravity and mass will be affected by the removal of some road components and addition of the rail conversion hardware. Based on the preliminary design as detailed in Section 4.0, a total of 1,900 kg of hardware will be removed from the vehicle which has a baseline empty weight of approximately 12,400 kg. The total installed equipment including snow-plow is estimated to have a mass of 4,000 kg, resulting in a new empty weight of 14,500 kg (a 17% increase). In the course of doing so, the centre of gravity is moved forward 0.3 m, resulting in an empty weight distribution of 42.5% front axle and 57.5% on the rear axle. The corresponding unmodified vehicle is 39%/51%. Fully loaded, the vehicle in modified form will weigh approximately 19,000 kg.

3.3 PROPULSION

The propulsion system was analysed from the points of view of adhesion, top speed, ability to cope with snow-plowing loads, overall gear ratio and fuel economy. It was an objective of the design to retain the standard coach drive line as much as possible and merely provide those interfacing elements, such as a dropbox, required to mate up with the proven Hurth drive axle gearbox.

3.3.1 Propulsion Requirements

To calculate typical fuel consumptions, the Thompson-Thicket-Portage-Pikwitonei route was taken to be a representative duty cycle. The following general requirements were also taken into account:

- Curb weight 14,500 kg, maximum weight 19,000 kg;
- Wheel diameter 763 mm new, 686 mm worn;
- Detroit Diesel Allison DDA 6V-92 TA, 229 kW Engine;
- Allison HT-740D Transmission with following ratios: 3.692, 2,021, 1.383, and 1.00;
- Maximum speed 100 km/h;
- Hurth Final Drive Gearbox 50/9 ratio, maximum input speed 4,500 RPM; and
- Maximum grade 3%.

3.3.2 Accessory Requirements

Accessory loads include the alternator, air compressor, air conditioning systems, and the cooling fans. These loads were estimated for the Railbus based on the known characteristics of the baseline bus as:

o	Alternator	7.5 kW	(including extra lighting load)
o	Air Compressor	3.7 kW	
o	Fan Drive	14.8 kW	
o	Air Conditioning	14.8 kW	
	Total	40.8 kW	

On an annual basis, based on equivalent intercity coach operation, the average accessory load was estimated at 50% of this total, or 20.4 kW, and this figure was used in fuel consumption estimates.

3.3.3 Engine and Driveline Efficiency

Considerable data was available on this particular engine and gearbox combination based on previous work carried out for Transport Canada (4). The driveline efficiency data used is summarized in Table 7.

EQUIVALENT OUTPUT SPEED KM/H	AUTOMATIC GEAR-BOX EFFICIENCY	FINAL DRIVE AND DROPBOX EFFICIENCY
16	80%	91%
32	85%	91%
48	87%	91%
70	88%	91%
100	88%	91%

TABLE 7: DRIVE LINE EFFICIENCY DATA

Depending on load and speed, the specific fuel consumption of the engine varies between 0.356 lb/BHP/hr and 0.341 lb/BHP/hr.

3.3.4 Summary of Propulsion Calculations

The Hurth gearbox is well matched to the wheel diameter selected and will allow a forward speed of 104 km/h, i.e., in excess of the design specification. The installed power is sufficient to allow climbing the specified 3% grade at 100% accessory load at a forward speed of 80 km/h. It is more than adequate for any required forward speed on a flat track.

In dense snow conditions (400 kg/m^3) snowploughing ability will probably be limited by traction rather than power, but the vehicle should be able to move off from standstill through approximately 1 m of snow.

In practice, acceleration may require limiting by adjusting the vehicle's throttle linkage and governor, because the 229 kW power unit will be capable of inducing drive wheel spin in some slippery rail conditions. As with the WCSS Railbus, use of a conventional coach accelerator pedal will allow easy modulation of power output to minimize this effect.

Calculated fuel consumption on the specified Thompson-Thicket-Portage-Pitwitonei route will be of order 22.6 l/100 km (12.5 mpg) unloaded and 23.4 l/100 km (12.1 mpg) fully loaded. The required gear ratio for the dropbox is 2.33, resulting in an engine RPM of 1800 in top gear at 100 km/h. The arrangement of the driveline is shown in Figure 10 (p. 54).

3.4 STRUCTURAL ANALYSIS

Although a minimum of modifications is planned to convert the MCI 102A2 bus to a Railbus, new single-axle truck frames are required. The severe shock and vibration loading of railway trucks requires a clear understanding of the stress levels in the frame in order to provide sufficient confidence in its durability and life expectancy. To this end, a subcontract was placed with the Manitoba Industrial Technology Centre (MITC) to perform finite element analysis of the front and rear subframes. The full scope of work of this subcontract is outlined as follows:

- Review of the vehicle requirements, based on their compatibility with the requirements for design of a railbus vehicle suitable for operation on Canadian Railway lines and under conditions normally found in northern, remote-service routes.

- Review of the applied loads and conditions provided to MITC by TTL, including track, equipment, vehicle, and environment-induced loads.

- Analysis of the front suspension subframe with respect to stress, fatigue, deflections, and principle modes of vibration, using finite element computer modelling techniques.

- Analysis of rear suspension subframe with respect to stresses, fatigue, deflections, and principle modes of vibration, using finite element computer modelling techniques.

- The following were to be provided as a part of the latter two tasks:
  - a map of the finite element model of the structure including element and mode identification;
  - summary of structure deflections and principle mode shapes; and
  - summary of principle vibration mode frequencies.

The stress analysis results indicated that the cross-members of the subframes required some strengthening, preferably by slightly deepening the sections, and that some local reinforcement by means of gussets was needed. In general stresses and deflections were acceptable (7). Dynamic analysis results showed that both subframes were dynamically stable, with only 3 modes of vibration having frequencies in the range of rail excitation, less than 30 Hz.

A sample map showing the finite element model of the front truck frame is shown in Figure 6.

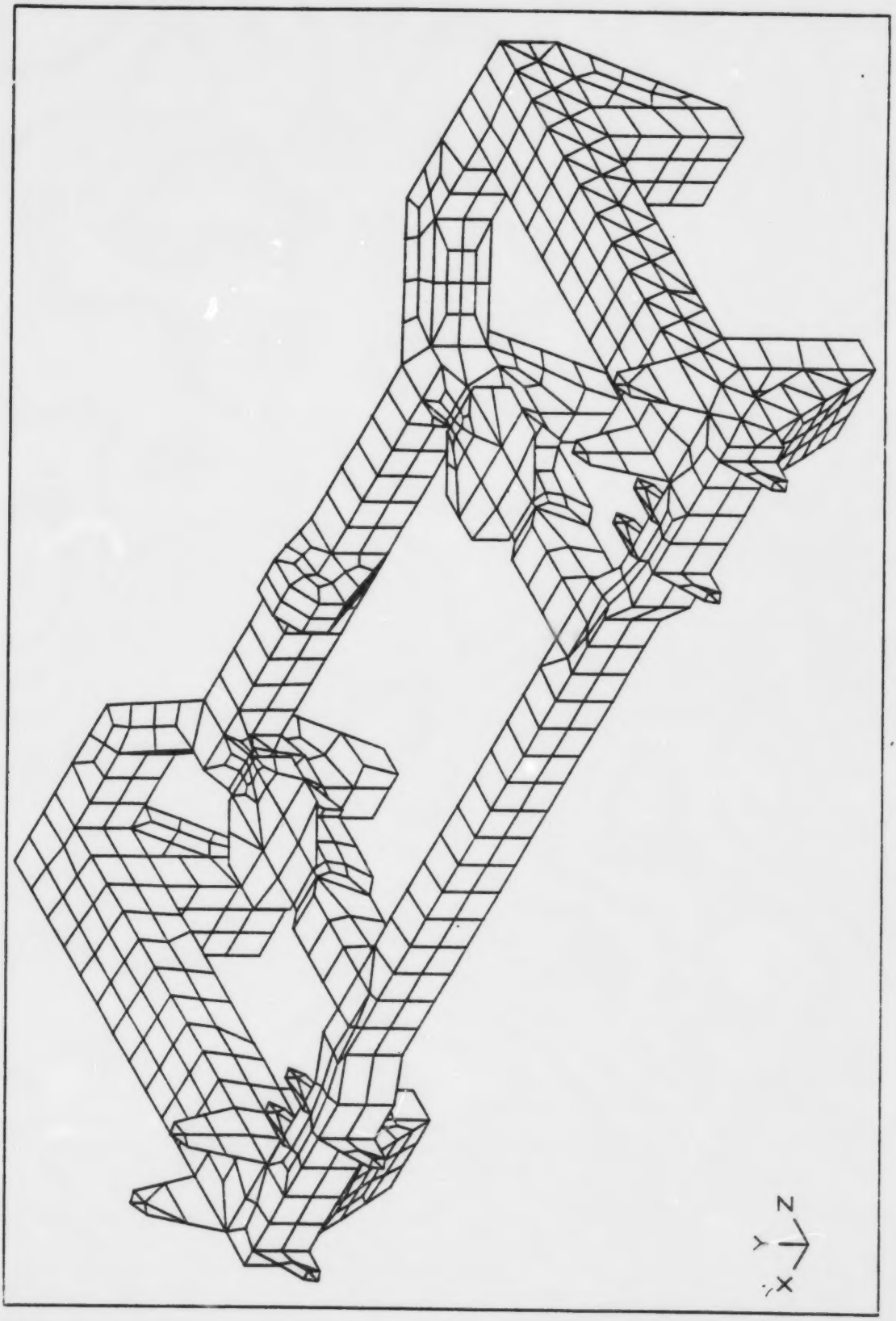


FIGURE 6: FRONT TRUCK FRAME FINITE ELEMENT MODEL

The structural analysis of the truck frame components is based on the loading conditions outlined in Appendix IV of Attachment A-3.

The results of the structural analysis will be used to aid final design selection of material properties and sizes. Areas where high stress concentrations are evident can be improved by minor redesign and strengthening.

3.5 BRAKE SYSTEM

3.5.1 General Requirements

Operating and design requirements pertinent to the brake system design are as follows:

- Mode of Operation - single unit or with light trailer
- Mass - 14,500 kg (empty) 19,000 kg (loaded)
- Duty cycle - infrequent braking
- Max speed - 100 km/h
- Deceleration - .89 m/s^2 (2 MPHPS) (service and emergency)
- Weight distribution - approx. 40/60 front/rear
- Temp. range -45 to +38°C
- Snow Depth - 100 mm of track snow (behind pilot)
- Services available - on-board compressed air and 24 Vdc electrics
- Design adhesion - nominal wheel adhesion .15
- Wind speed - 80 km/h maximum wind velocity
- Grade - 3% maximum grade (service conditions)
  - 5% maximum grade (park brake capacity)
- Special features:
  - minimum of 85% brake capability at all times (CTC regulations)
  - brake release capability for towing
  - use of existing equipment as much as possible
  - semi-private right-of-way (specified crossings)
  - parking brake
  - compatible with slide-prevention equipment.

3.5.2 Discussion of Systems

Three basic control methods are worthy of consideration: hydraulic, pneumatic, and a hybrid of these. Electric systems are not being considered here due to the nature of the vehicle and the lack of fully developed systems for rail use.

Hydraulic systems are most prevalent in automobile applications and have several distinct advantages over pneumatic systems. Hydraulic systems operate at high pressures, sometimes in the thousands of psi, and hence require smaller reservoirs and actuators. They also eliminate the need for compressors and large capacity storage tanks. Due to the physics of incompressible fluid flow, brake actuation response is almost instantaneous with

the braking command. This feature is more important on non-private right-of-ways where unscheduled stops are more prevalent. Some would argue that this property also provides a good "feel" to the brake pedal; however, this has more to do with what the operator is accustomed to. A properly trained operator will compensate for the system characteristics.

The drawback of hydraulics is the go-no go nature of the system. Any leak in the system renders the brake system helpless. This problem can be overcome somewhat by isolating the fore and aft systems or by use of duplicated or diagonal split systems. Nevertheless, careful inspection and maintenance procedures are necessary to ensure safe operation of the brake system.

Pneumatic systems are more frequently used in both heavy and light rail applications and heavy road vehicles. Leaks in the system are often compensated for by oversized compressors, making a more reliable system for tolerance of failures or poor maintenance practices. Lower pressures also make the system safer for maintenance personnel.

For the Railbus prototype application, a complete air system is provided with the bus, and hence any equipment-saving cost by going hydraulic is nullified. The equipment provided includes a complete brake package. Even if new actuators are purchased, the interface with the existing equipment should not require any major equipment changes. With a view to the future and any coupling of the vehicle to a second vehicle, it should also be considered that pneumatic signals are easily trainlined when compared to hydraulic systems.

A hybrid system of air over hydraulics can be a viable alternative. Such a system would use the present on-board braking system with hydraulic actuators. The advantage of this hybrid system is that response time is improved over air, and actuator size reduction makes for easier integration into an already crowded truck area. The problem with this is still the failure mode safety question inherent in hydraulics, although the amount of piping would be reduced significantly over an all hydraulic system.

3.5.3 Existing Bus System

A brief account of the existing bus braking control system is provided here to enhance understanding of the system for purposes of ensuring that functions of the system are maintained in the selection of the new system. Some of these features may be retained on the Railbus, but the features pertaining to the actuator are dependent on the type of equipment selected.

The operator modulates an air control signal through a mechanical (brake pedal linked)-pneumatic valve. This valve controls two separate lines for front and rear brake systems. These signals

are amplified through relay valves to provide brake cylinder pressure. A driver's parking brake is provided in the cab to apply reservoir pressure to the rear actuator. The parking brake overrides the service brake and can be released only by the release of the parking brake switch. A shuttle valve is provided which releases an emergency reservoir to the rear actuator when line pressure drops below a preset "safe" value. An inversion valve, in conjunction with the operation of the rear actuator, feeds a "brake lock" port on the rear actuator, which ensures continued application even after system air pressure is depleted. This lock mechanism cannot be released until system pressure again rises above a prescribed value.

These features provide a service brake which doubles as a parking brake and emergency brake in the event of system pressure loss. For more detail on the operation of the MCI 102A2 brake system, please refer to the maintenance manual (Reference 5).

3.5.4 Actuation Systems

There are a wide number of different actuation systems that could be considered for a Railbus.

Bus and truck brake systems are a natural consideration, as these would be designed to match many of the characteristics of the Railbus. At present, a bus drum brake system is being used for a prototype WCSS vehicle operating in Manitoba. The drum brake has proven unreliable in the heavy snow conditions due to ice build up on the drum. However, use of a "snow-brake" feature which continuously applies a low pressure to the brakes has eliminated this problem on the WCSS vehicle. Disc systems are slowly gaining acceptance and promise better performance and wear characteristics.

There are, however, other concerns with automotive-style brakes. Generally, the brake and actuator are integrated into the same unit on a bus. For a rail vehicle, the disc or drum must be connected to the axle, while the actuator portion connects to the truck frame. This causes difficulty due to relative motion between the two components as the axle yaws in the frame when the vehicle passes through a track curve and moves laterally on the primary suspension. This problem would be overcome if the actuator could be mounted on the bearing housing. A more serious consideration then becomes the vibration effects on these devices. On road vehicles, the brake equipment is mounted above the pneumatic tire which provides considerable isolation. On rail vehicles, the disc would be much more robust and would be mounted directly on the solid axle/wheelset, and the caliper is typically mounted above the primary suspension.

Automotive-style brakes are capable of performing the braking duties, but some development work would be required to adopt them to rail applications.

This elimination process has removed all but two brake systems that could be considered low risk: rail-style disc and tread brakes. Rail disc brake systems have been used extensively and have proven reliable and robust. However, for application on the preproduction prototype unit, an inboard disc cannot be used due to space restrictions on the rear axle. Further analysis of the impact of an outboard disc will be provided later.

Tread brake systems have also been used extensively in rail applications and show good operation and reliability, but this type of brake on the BREL Railbus has encountered some problems, as the brakes have had a tendency to freeze onto the wheel. An advantage of the tread brake, however, is that it tends to keep the wheel surface clean, which should help maintain a clean wheel/rail contact for purposes of signalling. (The signalling capability may become a problem for disc brakes on little-used lines on vehicles with relatively low axle loads.)

A review was carried out with the help of several potential system vendors, Knorr being most helpful with design data.

To utilize existing hardware, the disc would be mounted on an axle extension which, as an untested design, is not a desirable feature for this vehicle, and secondly, the actuator would extend beyond the skin line of the bus.

After further consideration it was determined that to provide an outboard disc, one of two things must be done: Either inboard bearings would have to be used, which would cause a major redesign of the truck area, or a new axle would need to be forged.

To reduce the protrusion of the disc brake unit beyond the bus side panel, the following can be done:

- Use an air-applied actuator (safe implementation to be discussed later).
- Reduce brake pad thickness from 24 to 14 mm (prototype only).
- Move the bearings inboard 30 mm and reduce size and deflections of chevron primary suspension lateral motion.

Disc thickness can also reduce the overhang, but at present Knorr does not have a narrower disc available (more complete duty cycle information would be required for thermal design of a new smaller disc). All of this brings the outside limit of the brake equipment to within a few millimeters of the edge of the bus skin, which would be sufficient for operation of a prototype/ preproduction unit, but should be brought in further by truck redesign to inboard bearing type for a production vehicle. Inboard bearing truck design is not a candidate for the preproduction prototype vehicle, since the overall costs would be prohibitive.

Knorr also provided information on tread brake actuators. A typical layout is shown in TTL Drawing No. 339-110-009 (Attachment A-2). This system uses the available axles and is shown with the smaller air-applied actuator. The brake linkages allow the actuator to be moved above the wheel and, with some modification, a spring-applied actuator could be used if deemed necessary.

After review of these two systems, it is concluded that the tread brake application was preferred on the grounds of simplicity, cost, and redundancy (four actuators per car set).

3.5.5 Slide Prevention Equipment

The Railbus, although not a new concept, offers some unique demands. With this in mind, design requirements which are often standard in bus or rail operations may not necessarily be strictly applied to the Railbus.

One area which is worthy of consideration is the apparent requirement for slide prevention equipment. In general, these systems work on the brake control side to modulate brake forces with respect to available wheel adhesion, providing (ideally) the minimum stopping distance possible. A second function of these systems is to prevent wheel lock-up and the resulting wheel flats that can occur.

With respect to the wheel flats, a number of criteria have effect on their probability of occurrence. The braking duty cycle is very low and potentially may occur only at widely placed station stops. The limited-access private right-of-way reduces the number of potential emergency stops. The maximum brake demand of 2.0 MPHPS, with distributed braking, rarely requires adhesion levels greater than 0.1, and although there is disagreement of figures from different sources, most quote reliable adhesion levels of between 0.1 and 0.15, hence reducing the probability of slide occurrence.

The second approach to the question is that minor wheel flats in this application may not be as serious a problem as in other types of systems (such as rapid transit in noise sensitive built-up areas). The targeted routes all have non-continuous rail that creates noise and vibration equal to or greater than that caused by minor wheel flats. Also, with an air bag suspension, much of the vibration will be filtered before reaching the bus body. From a maintenance standpoint, the inclusion of complex sensing, control and brake application equipment might introduce more operating cost than the equipment and labour involved in occasional wheel grinding. Finally, the capital cost of the slide prevention equipment, although not prohibitive, is still extra cost that may not be necessary. Although slide prevention compatibility should still be built into the purchased brake equipment, it is suggested that operation or testing of the Railbus proceed before more potentially unnecessary equipment be procured.

3.5.6 Safety Considerations

The safety aspects of any braking system are always of high priority. The requirements again vary with the operating scenario. The rail industry generally has a requirement that 85% braking be available at all times after a single unit failure. For a Railbus with only 2 axles this becomes difficult to achieve, as four independent braking units would need to be installed per axle to ensure that this requirement is met in the case of a single-unit failure. Of course, for a multiple unit train, braking is assisted by all axles and the requirement is more easily met.

Other safety questions arise out of the actuation methods and the result of any breakdowns of the equipment. The original road bus employs air-on actuators with an emergency reservoir that would be switched to the actuator when service pressure drops below a safe operating value. Further to this is an automatic mechanical lock on the actuator's piston collar that holds the brake on even after air has completely leaked out of the air system.

For the Railbus the safety factor may not have to be as stringent, because the private right-of-way ensures a lower probability of collision than for a road-going bus. It would still be necessary to provide an emergency reservoir system for an air-applied brake, but the parking brake could be manually applied either from the cab or at the brake, as is common in rail operations. For a spring-applied brake, both the emergency and parking capabilities are easily handled, but a problem can arise when there is a necessity to tow an unpowered vehicle. In this case the brakes would need a mechanical cutout feature that might be considered a safety problem if no insurance system is devised to ensure a reset before the vehicle is again powered up. Alternatively, a brake pipe line with a glad-hand fitting compatible with existing railroad equipment could be utilized.

3.5.7 Summary of Brake System Considerations

The following salient points should be considered for selection of a Railbus brake system concept:

- Of the actuation systems, two concepts appear promising: the outboard disc and the tread brake. The outboard disc is difficult to integrate with the present axle equipment configuration and may require forging a new axle. The performance of the disc system is anticipated to be reliable and provide a relatively consistent brake rate. The tread brake is more easily integrated with the vehicle and can provide a greater level of redundant braking and can provide wheel cleaning for signalling. Performance is suspect only insofar as the British Rail prototype has had some freezing-on of brakes, which is at least a failsafe mode. Ballpark cost figures provided off-the-record by vendors indicate the price of the four-unit tread brake system to be approximately double the cost of the two-unit disc brake system.

- Air as actuation control is recommended on the grounds of simplicity, safety, and cost. A proven air brake control system is available at present on the bus, but proper care should be taken when integrating this with new mechanical systems components.

- Slide prevention equipment is not deemed necessary for preproduction prototype construction and should be included only if operation of the Railbus indicates a high occurrence of wheel lock-up. The proposed anti-slide system requires that the actuators be air-applied.

- If an air-applied actuator is selected for the prototype design, mechanically operated parking brakes should be included on at least one axle.

- A case for reduced brake capability for emergency needs to be discussed with the selected route authority to ensure that the selected brake system does not contravene specified route-operating requirements in emergency operation.

It should be noted that the discussion and recommendations are considered only for the preproduction prototype vehicle and that for a production vehicle the brake system be integrated further with the designs of all vehicle systems.

3.6 BI-DIRECTIONAL OPERATION

One of the more critical elements of the work related to this study is the means of achieving bi-directional operation. The alternatives postulated for achieving this end were:

- On-vehicle turntable;
- In-track turntable;
- Track wyes and loops;
- Provision of two full cab-ends;
- Provision of simplified rear drivers station;
- Two vehicles back-to-back; and
- Use of rear-vision aids.

In the following subsections these techniques are discussed and compared on economic, operational, and technical grounds, and recommendations made for incorporation into the prototype.

3.6.1 On-vehicle Turntable

This method is used on a number of types of track-repair equipment and early primitive types of railbus. A more up-to-date design was installed on the WCSS railbus and has been extensively tested on the INCO and CN railway lines in Thompson, Manitoba (3). It was found that there were a number of deficiencies in the detail design of the equipment which resulted in costly downtime and repair work. After modifications to improve the "four-poster" hydraulic mechanism, the system has performed reasonably well.

The partial success led to a detailed study of the possibility of applying a turntable to the new vehicle. Areas of concern were:

- o Structural modifications to the bus;
- o Engagement in the rail;
- o Precision in re-alignment after rotation;
- o Size, weight, and cost of the mechanism; and
- o Simplicity in lifting mechanism.

An extensive preliminary design was carried out by Chadwick Engineering Ltd. of such a device which was designed to be mounted in the central luggage compartment. The selected mechanism was a scissors-type jack with two lifting rams which had a feature that gripped the rail-head to aid in resisting side-forces and allow easy re-alignment. Locks were provided for the down and up positions, and the system would be capable of automation. It was considered possible to reinforce the bus structure, but at the expense of increased weight. The monocoque design of the MCI coach does not lend itself to this design solution, but there is sufficient room, and a workable system could be developed.

The added weight would be 1100 kg for the turntable and perhaps 100 kg for reinforcing at a capital cost of approximately $20,000.

The major difficulty with this solution is the operational aspect. Problems were frequently experienced with the WCSS turntable in achieving correct operation in snow conditions, largely because of obscured operator vision. Reliability will always be a problem, necessitating frequent servicing if trouble is to be avoided, and it is likely that proper approvals will not be gained for rotating the vehicle when loaded with passengers. This would necessitate unloading and then loading all passengers. Other difficulties can be envisaged, such as encountering high snow banks on either side of the track, which would prevent rotation. A single-ended vehicle is depicted in Figure 7.

3.6.2 Track-Based Turntable

This solution, in both powered and unpowered versions, has been frequently used in the past for reversing all types of equipment up to and including locomotives. In moderate climates this is a simple solution. In the Canadian remote-services applications, the design would be complicated by the required resistance to snow and ice build-ups. An additional factor is the capital cost of the required numbers of these turntables in suitable locations, and the possibility that installation would be required where poor ground conditions existed.

3.6.3 Track Wyes and Loops

In a number of potential locations identified in the review of service requirements (Attachment A-1), wyes already exist. The concept is that a lightweight, low-grade turning track, or wye,

would be installed only at those locations where required. This solution is simple, conventional, and readily accepted, but is likely to be very expensive in terms of capital cost and switch maintenance. (Problems can also be experienced in severe icing conditions.)

3.6.4 Provision of Two Full Cab-Ends

This design solution was implemented on the early bi-directional Type 141 BREL Railbuses. In the current application the vehicle to be converted is rear-engined, necessitating a "pod" to be grafted onto the rear of the vehicle behind the engine. This would increase an already rear-ward weight bias and necessitate considerable structural modification in a highly stressed area of the bus. Additional difficulties that would be encountered are the weight and cost of such a complete cab-unit with doors, glazing, instrumentation, heating etc. Engine access would be made considerably more difficult. It was concluded that this option is possible but not particularly attractive.

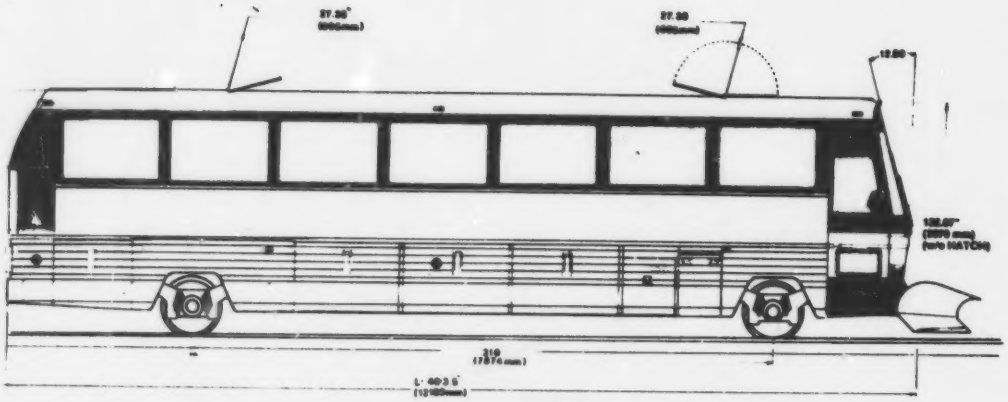
3.6.5 Provision of Simplified Rear-Driver Station

Layout drawings and investigation of the space and equipment required to provide a slightly simplified driver's station at the rear of the vehicle were carried out, and the concept is shown in Drawing E339-110-008, "Two Position Driver Railbus" (Attachment A-2). It was concluded that there was more than adequate room and angles of vision for this design solution, which would necessitate only minor structural modifications and the addition of instruments, controls, windshields, lights, defrost/demist system, windshield wipers, etc.

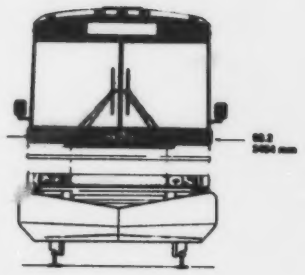
A reduced-depth windshield would be used to allow unobstructed access to the engine and accessories mounted below. Seating accommodation would still be 40, and weight would only be marginally increased. Cost of the additional equipment is in the order of $20,000 (same as a turntable). The technical risk is largely in the degree of interconnection to the controls. Operationally, this system would be satisfactory (side and end views are shown in Figure 8). The field of vision of the rear cab is somewhat limited by the toilet installation. Relocation is feasible but would add cost. There is in addition some scope for improvement by relocation of the drivers seat.

3.6.6 Two Vehicles Back-to-Back

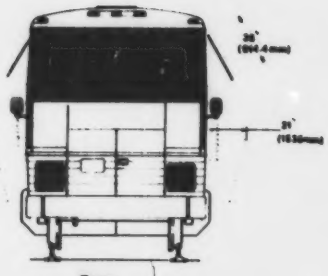
This arrangement would provide complete redundancy of all mechanical and electrical systems, doubled payload volume, and the possibility of carrying freight in one of the two units. Full control would be possible from either end. It would be possible to limit the degree of vehicle modification required to the coupling arrangement and control lines.



Right Side



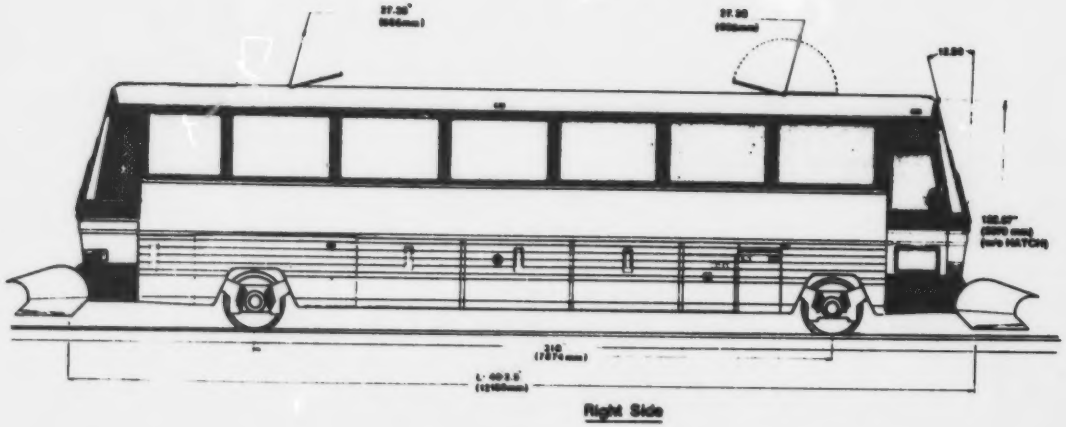
Front

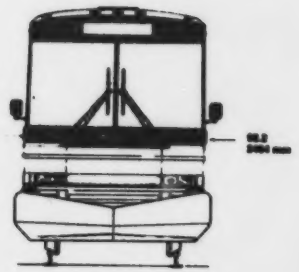


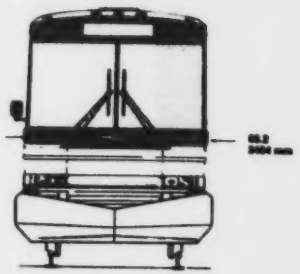
Rear

CANADIAN ADVANCED DESIGN RAILBUS

FIGURE 7: SINGLE-ENDED RAILBUS CONCEPT







CANADIAN ADVANCED DESIGN RAILBUS

FIGURE 8: DOUBLE-ENDED RAILBUS CONCEPT

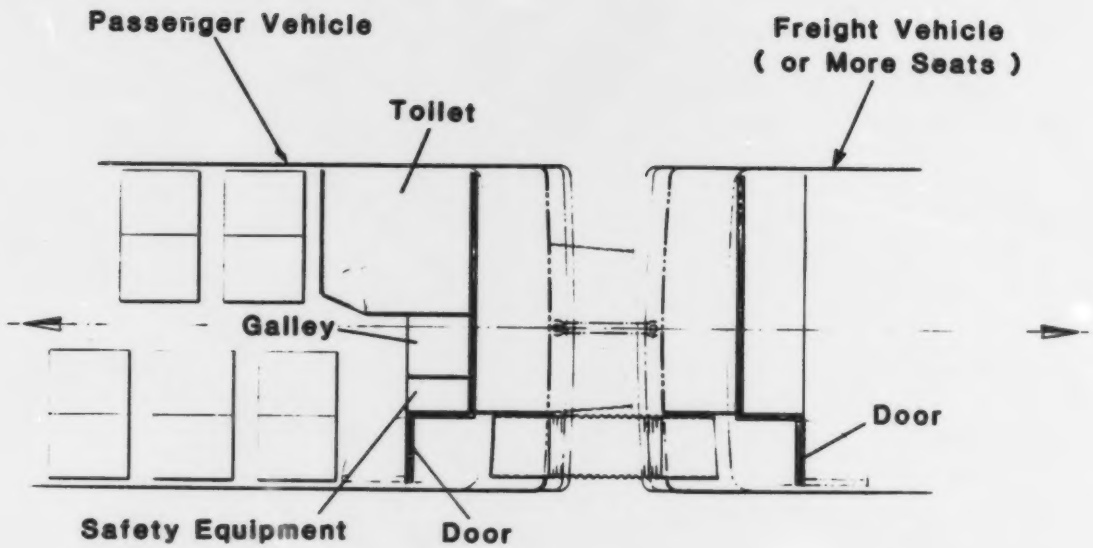


FIGURE 9: VEHICLE INTERCONNECTION

It is also possible to provide an interconnecting passageway, intended for operating crew use only, between the two units as shown in Figure 9. The major disadvantage associated with this concept is the necessity for two complete vehicles, which, depending on interior fit and finish of the second unit, virtually doubles the cost.

The proposed vehicle interconnect concept is preliminary in nature and would require considerable attention at the detail design stage.

3.6.7 Rear Vision Aids

One concept that has been proposed is to use rear vision systems such as TV cameras and continue to drive the vehicle from the single driver's stations. It is extremely unlikely that this will be satisfactory in an operational setting.

3.6.8 Summary

Based on the review carried out, it was concluded that for lightly utilized remote-service applications:

- Track-based turning systems are inflexible and costly;
- A turntable is technically feasible but has significant operational disadvantages;
- Provision of two full cab arrangements would aggravate weight distribution problems and be unneccessarily complex;
- Provision of rear-vision systems would be operationally unacceptable;
- For the prototype a simplified rear-driver's station is recommended; and
- Where traffic volume justifies it, a double back-to-back vehicle be used for production systems.

4.0 PRELIMINARY DESIGN

Preliminary design concepts have been prepared for the Railbus and are provided as Attachment A-2 "Preliminary Design Drawings." The preliminary design drawings are based on an MCI 102A2 intercity bus and are prepared with the requirements of the "Design Specification" Attachment A-3 in mind. The following subsections provide a brief discussion of the preliminary design solutions.

In general, the Railbus preliminary design consists of a standard MCI 102A2 bus with the road wheels and axles removed and replaced with new design railway single-axle trucks at the front and rear wheel wells. Railway brake systems are incorporated, and railway axles, wheels, and bearings are utilized. A driveline interface between the automatic transmission and the axle is provided by an existing right angle drive gearbox/coupling and a new design dropbox/reverser. Other modifications made to the bus include the addition of a pilot and towbar to both ends of the vehicle, necessary changes in exterior lights, bell and horn, and incorporation of railway safety equipment. A number of the bus subsystems are also modified to interface correctly with the new equipment mentioned above, and includes modifications to the hydraulic system, pneumatic system, electrical system and interior arrangement, as well as some structural modifications.

4.1 REAR TRUCK SUBFRAME AND SUSPENSION

The rear truck frame preliminary design is shown in Attachment A-2 as Drawing No. E339-110-005.

The rear truck frame is of fabricated box frame design. Basic material is CSA G40.21 grade 44 W and is 5 mm (3/16") thick. Estimated weight is 240 kg. The rear truck frame utilizes the four existing rolling lobe airbags as the secondary suspension, with two point leveling, thus minimizing the changes required to the bus wheel well structure. Only the relocation of the attachment brackets, such as brake valves etc., is anticipated at the rear wheel well. A pair of air reservoirs may be dictated by the detailed analysis, in which case they will be incorporated in the wheel well as shown in Attachment A-2 Drawing No. E339-110-017. The existing traction/radius rods will be replaced with shorter versions, and the top "A" frame mounting arrangement may be modified to allow for changes dictated by the final design dynamic analysis.

The rear truck frame provides three mounting points for a Hurth right angle drive gearbox described later.

The box frame structure also extends beyond the wheels to provide a suitable mounting location over the outboard bearings for railway-type rubber laminated chevron primary suspension units. The purpose of the primary suspension units is to provide

reasonable isolation of the truck frame (and any equipment mounted on it) from the high shock and vibration loads consistent with railway applications. The primary suspension units mount directly onto the bearing housing on the axle and to an adjustable bracket on the truck frame, similar to other existing railway applications. The adjustability is required to shim for creep (sag) in the chevron units. A tie-bar located under the primary suspension units and mounted to the truck frame provides retention of the wheelset and chevron assembly when jacking the Railbus or in the event of a derailment.

Also provided on the track frame are mounting points for the existing anti-roll bar. A preliminary design, Drawing No. C339-110-014, Sheet 2, is provided in Attachment A-2, showing the relocation and attachment of the anti-roll bar.

The rear truck frame also provides mounting locations for two brake actuator units, to be discussed later. Compatibility with hot box detection equipment would be investigated at the detail design stage.

4.2 REAR DRIVE TRAIN

Two options were pursued during the preliminary design stage of the Railbus. These options are based on the existing MCI 102A2 model angled-position engine shown in Attachment A-2 as Drawing No. E339-110-010, and an inline engine position presently used on MCI 102A3 bus models shown as Drawing No. E339-110-013, Sheets 1 and 2. The latter option is much tidier and provides additional space for the dropbox/reverser, but requires costly removal of the engine/transmission and replacement of the engine subframe for the prototype Railbus. The existing angled-position engine is the preferred arrangement for the preproduction prototype Railbus due to the anticipated cost savings; but for a production Railbus, the inline drive would be preferred for reasons of maintenance, accessibility, and extended drive train life (equal angle universal joints).

As a general note, the Railbus body is located 50 mm higher than the existing bus in order to allow sufficient clearance between the cardan shaft and the Hurth gearbox.

A sketch of the drive train arrangement is shown in Figure 10.

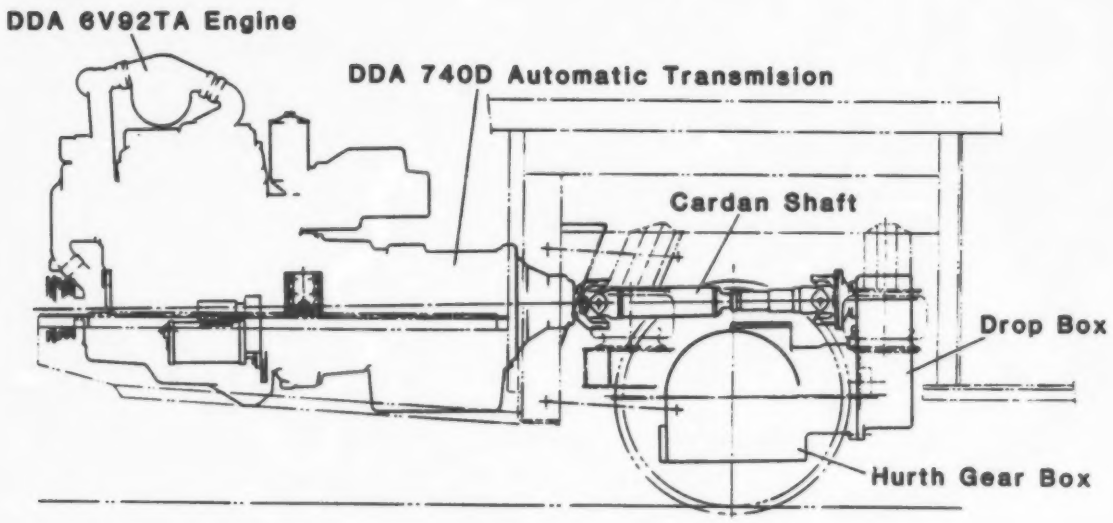


FIGURE 10: DRIVE TRAIN ARRANGEMENT

The power plant is a standard North American Detroit Diesel Engine 6V92TA with an Allison 740D automatic transmission. A standard universal joint cardan shaft drives a dropbox/reverser from the automatic transmission. The dropbox/reverser mounts directly to a railway type fully bi-directional right-angled drive Hurth gearbox which drives the axle via a flexible coupling.

The individual drive train components are as follows:

Engine:	Turbocharged DDA 6V92TA diesel, producing 307 horsepower at 1800 rpm.
Transmission:	Allison 740D automatic automotive transmission, with lock-up in top gears.
Cardan Shaft:	Standard SAE flange-mounted needle-bearing universal joints with splined shaft.
Dropbox/ Reverser:	A heavy duty dropbox with integral reverser designed to meet the space constraints of the Railbus. The dropbox not only provides for the large vertical offset between the transmission centreline and the axle gearbox input shaft centreline, but also provides the necessary step-up in shaft speed required to match the engine speed to the correct vehicle running speed. The reverser will include equal full power performance in both the forward and reverse directions, and will have the capability to decouple the drive axle rom engine power. High quality gearing will ɔe utilized to minimize noise and vibration. The dropbox/reverser lubrication will be self-contained, and accessible oil fill and drain plugs will be provided. A suitable inspection cover will be provided.
GearBox/ Coupling:	A right angle drive Hurth gearbox will be provided, which mates to the dropbox/reverser. The Hurth gearbox/coupling is similar to the unit presently used by the Toronto CLRV streetcars. The gearbox mounts on resilient bushings to the rear truck frame. The gearbox provides sufficient clearance around the axle to allow for primary suspension motions and has a 50/9 reduction ratio. The gearbox lubrication is self-contained, and accessible oil fill and drain plugs are provided. A suitable inspection cover is also provided. A flexible drive coupling capable of operating under full power in both directions is provided.

4.3 FRONT TRUCK SUBFRAME AND SUSPENSION

The front truck frame preliminary design is shown in Attachment A-2 as Drawing No. E339-110-011.

The front truck subframe is very similar to the rear truck frame described in 4.1; fabricated design is used, CSA G40.21 grade 44 W steel is the primary material used, weight is estimated to be similar, identical primary suspension chevron spring arrangements are used, and identical brake actuator amounts are employed.

In contrast, however, the front truck frame secondary suspension involves only two existing rolling lobe airbags with single point leveling. Since the front axle is not driven, no mount points for a gearbox are provided, and the traction rods are shortened from the existing units with no modification to the bus mount points anticipated for the traction rods. The top "A" frame mounting is provided in place of the existing lateral "Panhard" rod, since the air springs required relocation toward the centreline of the bus; however, this arrangement may be modified to allow for changes dictated by the detailed dynamic analysis.

Some changes are required to the bus wheel well structure in order to allow the airbags to be moved inboard sufficiently to clear the rail wheels. This modification is limited to add-on structure to provide a mount surface for the airbag, and the removal of the portion of the existing airbag mount which protrudes beyond the main wheel well beams.

A single supplementary secondary suspension air reservoir may be dictated by the detailed dynamic analysis, in which case it will be located within the confines of the wheel well as depicted on Drawing No. C339-110-017 in Attachment A-2.

4.4 TREAD BRAKE DESIGN

Many types of brake systems were investigated, including inboard disc, outboard disc, cheek disc, automotive and tread brake systems. The trade-offs and concerns are highlighted in Section 3.5 of this report. The rugged design, simple maintenance, easy access, and cost effectiveness of the tread brake system were the primary reason for specifying the tread brake system for the Railbus. The added benefit of wheel cleaning for improved signalling was also a factor, as well as the fact that consistently high brake rates similar to those required on streetcars is not required for dedicated Rail service. The lower cost of the tread brake units also allowed the additional redundancy of four actuator units rather than just two.

A proposed tread brake configuration is shown in Attachment A-2, Drawing No. E339-110-009, Sheets 1 and 2. This drawing actually is designed around a Knorr air-applied actuator and tread brake hanger and shoe holder; however, it is clear that most other brake manufacturers equipment could also be employed.

Several other vendors are in fact investigating the application of a tread brake unit and are expected to respond in the detail design stage. At that point, the appropriate equipment will be selected. The design requirements are outlined in the Design Specification Attachment A-3. Features of the brake system are summarized as follows:

- o The brake system utilizes the existing on-board pneumatic system with a minimum of modification.
- o The brake system complies with all railroad governing regulations.
- o A brake pipe with suitable glad-hand fittings is provided to allow recovery from either end of the vehicle by existing railroad equipment. A suitable deadman control is incorporated with the brake pipe.
- o Nominal deceleration will be 0.89 m/s^2 (2.0 MPHPS) on tangent level track. Minimum brake rates will be 0.80 m/s^2 (1.8 MPHPS). The service brakes are air applied.
- o The service brake equipment will be compatible with available anti-slide equipment, and both front and rear brake rates are independently adjustable. The service brake air system is isolated from all other air system functions such that service brakes are operable in the event of a failure in the remainder of the air system.
- o Emergency brake rates are equal to full service brake rates. Venting of the brake pipe causes full emergency brakes to be applied.
- o An air-operated park brake is applied by the release of the deadman and is capable of holding the vehicle on a 5% grade. A spring-applied or a mechanical override park brake operated from a location near the front entry door will also be provided.
- o Some changes to the existing air system are required to provide the necessary braking features, and these changes are discussed in a subsequent section.

4.5 SNOW-PLOW PILOT/TOWBAR

The preliminary design of the Pilot and Towbar arrangement is shown in Attachment A-2, Drawing No. E339-110-004. A towbar arrangement for the rear of a uni-direction vehicle is also shown in Drawing No. E339-110-012. The latter towbar arrangement will not be used on the bi-directional preproduction prototype Railbus, but a similar arrangement could be used for a production Railbus based on two back-to-back vehicles.

The rear towbar was originally conceived for the possible turntable arrangement for bi-directional operation similar to the WCSS Railbus presently operating in Northern Manitoba.

The turntable concept has been dropped in favour of a second driver's cab at the rear of the Railbus in order to provide bi-directional operation for the Prototype Railbus. The arguments are provided in Section 3.6, but generally relate to operational difficulties, safety, structural considerations, and cost.

For the preproduction prototype Railbus, a pilot/towbar assembly will therefore be provided at both ends. The pilot is fully adjustable on ribbed mounting faces and is fastened to the main structural members which are designed to take the bumper loads on the existing bus.

The pilot is easily removable from the bus end frame structure. Fixtures provided on the structure of the pilot will allow jacking or lifting of the vehicle. The pilot is of fabricated design and material is CSA G40.21 grade 44W low carbon steel.

Provision is made on the Pilot for attachment of an easily removable towbar which is stored in the forward underfloor baggage compartment. The towbar is capable of mating safely to existing railroad equipment and is modelled after the existing WCSS towbar.

Both the pilot and towbar are capable of withstanding a buff and draft jerk load equivalent to ±2 g acceleration of a loaded Railbus. Provision is made in the towbar for some cushioning of the buff/draft loads. The towbar attachment points on the Railbus are suitable for semi-permanent drawbar attachment of a light-weight baggage trailer. The rear attachment is suitable for semi-permanent coupling of back-to-back vehicles.

4.6 LIGHTS, BELL AND HORN

A preliminary design showing the end of car lighting arrangement is shown in Attachment A-2, Drawing No. C339-110-016. This drawing, however, is shown for a uni-directional Railbus. For the preproduction prototype Railbus, the front view of the Railbus will be simply duplicated for both ends of the vehicle.

The intention is to place the headlights and the marker lights in the area above the existing windshield which normally carries the destination sign. The train number box is proposed to be located in the lower right-hand corner of the windshield, looking out from inside the bus.

Ditchlights are proposed to be provided by the existing four-unit sealed-beam headlights. The headlights are proposed to have sufficient capacity to allow the driver to distinguish a man dressed in dark clothing at a range of 183 m (600 ft). This is somewhat less than the present regulations specify (800 ft), but the reduced capacity is likely to be appropriate since both the maximum operating speed and the braking distance of the Railbus are much lower than for most main line locomotives.

4.7 ACCESS PROVISIONS

No changes to the existing bus access provisions are planned for the pre-production prototype vehicle. Additional doors could be fitted for production vehicles. A single passenger entry door is provided at the front of the Railbus, two emergency escape hatches are provided in the roof, and all major side windows are easily openable in a emergency. MCI has also provided excellent access to underfloor baggage, where six large access doors are provided (three on each side of the body).

Access doors are also provided for the engine compartment, blower fans, engine filter, A/C compressor, lavatory service, radiator fill, air reservoirs, A/C radiator, fuel tank, batteries, windshield washer/auxiliary equipment, and main terminal/relay panel.

4.8 MODIFICATIONS TO THE EXISTING BUS STRUCTURE

Modifications of the existing bus structure are kept to a minimum. Any modifications which are made ensure that compatibility of materials and impact on the remaining structure are taken into account.

Modifications to the bus structure in the wheel well areas are described in previous truck frame sections. However, a possible change to the wheel well structure and body panels is the removal of the rubber wheel well skirts and replacement with support structure and body side panels shaped to match the smaller wheel diameter. The wheel well will remain clear, allowing easy inspection of the brakes and axle bearings.

The most extensive structural modifications will take place at the rear of the bus where the addition of the rear driver's cab requires reworking of the upper end of frame structure to accept a reduced-height windshield. This arrangement also requires relocation of the engine air intake duct, the engine coolant surge tank, etc. The addition of a new end frame will be trimmed with body metal and sealed against the outside environment.

Some modification of the front and rear end structure will be made to accept the replacement of the bumpers with the pilot/towbar assemblies. These changes will be limited to weld-on prefabricated mount brackets. The existing bumper supports are capable of resisting a buff load of at least 50 tonnes.

Other modifications to the bus body include removal of unnecessary external lighting and fixtures, and suitable repair and sealing of the resulting openings through the bus exterior skin.

4.9 MODIFICATIONS TO THE HYDRAULIC SYSTEM

The hydraulic system provided on the Railbus will not be used and will therefore be disconnected; however, it will be left in place should a need for hydraulic power arise (i.e., possible hydraulic winch).

4.10 MODIFICATIONS TO THE PNEUMATIC SYSTEM

The proposed changes to the pneumatic system are shown schematically in Attachment A-2, Drawing No. D339-110-018.

A brake pipe line is added, including shut-off cocks and glad-hand fittings. This line actually utilizes an existing air line on the bus which functions in the same way as a railway brake pipe line.

The air system on the bus can be charged from the brake pipe line through a one-way check valve; subsequent venting of the brake pipe line does not allow the air system to discharge. The push-pull park brake valve is replaced with a deadman control. A deadman isolation cock is provided in order to allow towing of the railbus by existing railway equipment.

Two pilot-operated check valves have been set in the service-brake vent lines for the front and rear brakes, which are normally open when brake pipe pressure is present; but when the brake pipe is vented, calling for emergency brakes, the service brake vent line is closed.

An additional inversion valve and pressure regulator are provided at the front axle to provide full emergency brakes at that axle as well as the rear axle.

Auxiliary air reservoirs for the secondary suspension may be dictated by the detailed dynamic analysis, in which case they will be installed in the wheel well areas.

An additional air reservoir will be located in the front spare tire compartment to operate the horn, and will be filled from the air system downstream from the isolated service brake system. (The service brake reservoir and system pressure are protected by a 65 psi regulator that ensures quick charging of the service brake system prior to charging the rest of the air system.)

Duplication of air-operated wipers and horns will be provided at the rear of the Railbus, and isolation of the unoccupied cab end controls will be incorporated in the detailed design stage.

4.11 MODIFICATIONS TO THE ELECTRICAL SYSTEM

Additional switches and indicator lamps will be added to the control panels of the front and rear cab to provide the necessary interface between new and existing electrics. A suitable relay panel and lock-out feature will be provided in order to isolate the unoccupied driver's cab.

All unnecessary exterior lighting on the bus will be removed and the wiring suitably terminated.

4.12 MODIFICATIONS TO THE INTERIOR ARRANGEMENT

Although modifications to the interior of the prototype vehicle will be limited to the addition of a rear driver's cab and a pair of reversible seats, a production married pair Railbus could have imaginative seating arrangements including 50% forward- and rear-facing seats, side wall seats, or any combination of these.

The rear driver's cab concept is shown in Attachment A-2 Drawing No. E339-110-008, and is further described in a previous section of this document on bi-directional operation (Section 3-6).

4.13 RERAILING PROVISIONS

Rerailing provisions on the prototype railbus will be limited to towing and lifting eyes, and jacking pad locations at the wheel wells and the pilots. Special equipment will include such items as butterfly ramps, crowbar, and sledge hammer, jack and come-along.

4.14 SPECIAL SAFETY EQUIPMENT

Special safety equipment will include the following:

- o A cabinet containing the following items will be provided adjacent to the entry door in the passenger compartment of the Railbus:
  - a red flag on a staff;
  - a white light;
  - torpedoes; and
  - fuses.
- o A 17 pound dry powder fire extinguisher will also be provided adjacent to the entry door in the passenger compartment.
- o An emergency tool kit will be provided at the rear end of the passenger compartment consisting of the following items:
  - one 2.7 kg sledge hammer (6 lb);
  - one 2.0 kg axe (4½ lb); and
  - a hand saw.

- Other emergency equipment which will be provided on the vehicle includes the following:
  - a stretcher;
  - a first aid kit;
  - a shovel;
  - a pike;
  - a crow-bar; and
  - a switch broom.
- A suitable two-way FM radio capable of providing communication with the train dispatcher and other railway employees will be provided in each cab.
- Emergency heating equipment will be provided independent of engine power. This heating system will be capable of maintaining a 10°C interior temperature for a 24-hour period for outside ambient temperatures as low as -40°C and with a wind velocity of 50 km/h.

4.15 PROVISIONS FOR HANDICAPPED AND ELDERLY

A hydraulic wheelchair lift will be offered as an option on a production Railbus. Provision for handicapped access on the prototype Railbus, however, will be limited to use of larger seat spacing and seat width. In addition, an area shall be set aside as provision for a potential retrofit of a suitable wheelchair-handling unit. To assist the elderly, a retractable entry door step will be provided on the preproduction prototype bus.

4.16 BAGGAGE TRAILER

For the purposes of tow hitch design and developing a preliminary cost estimate, a simple baggage trailer for typical payloads including oil drums, canoes, baggage and snow-mobiles of the following characteristics was assumed:

- length 6.0 m;
- width 2.5 m;
- height 2.6 m;
- construction of steel tube and riveted skin (same as bus) with rectangular box section underframe;
- two single axles with 450 mm wheels and compliant rubber bush suspension;
- empty weight 2.5 tonnes (approx.);
- maximum loaded weight 5 tonnes (approx.): and
- floor height 0.6 m.

5.0 DESIGN SPECIFICATION

The Design Specification for the Canadian Advanced Railbus for Canadian remote-rail applications is provided in its entirety as Attachment A-3.

In order to take full advantage of the Railbus technology cost benefits, a standard production MCI 102A2 intercity highway bus is used as a baseline vehicle. Only those modifications absolutely necessary to meet the relevant performance, operational, regulatory, and safety requirements have been made. The Design Specification is based on all relevant Canadian Motor Vehicle Safety Standards (CMVSS), US Federal Motor Vehicle Safety Standards (FMVSS), the relevant performance and operational requirements set out by the Canadian Transport Commission (CTC) and the Unified Code of Operating Rules (UCOR), and the performance studies documented in TTL Report No. 339-511-001, "Operating and Service Requirements for Advanced Railbus" included here as Attachment A-1, and TTL Report No. 339-512-001, "Technical and Regulatory Requirements for Railbus Acceptance on Canadian Railways" which latter document is summarized extensively in Section 2 of this report.

6.0 COST ESTIMATE

A preliminary cost estimate was prepared for the two selected configurations of interest, namely the bi-directional single vehicle and the back-to-back married pair. The following sources for cost data were used:

- Coach costs were based on the purchase price of the preproduction prototype vehicle, with suitable allowance for equipment not included in the prototype (e.g., mini-galley).
- Credit for removed (or not supplied) road equipment was based on experience with the current prototype program.
- Rail conversion hardware costs were based on current costs consistent with current light rail product markets.
- Miscellaneous special equipment costs were based on experience from the WCSS program.
- Conversion labour was estimated as a ratio based on the total work content of a new coach, and assumed a design suitable for the production of a batch of up to 20 vehicles to be carried out in Manitoba at MCI or some other suitable location nearby.
- A small management and production team was assumed to modify the design where required, based on prototype evaluation.

The results of the work are shown in Table 8. They are illuminating in that a single bi-directional unit is estimated to cost approximately $360,000 and a married pair with one unit configured for freight approximately $645,000. This compares well with estimates for foreign Railbus technology, some of which will cost in the area of $1,200,000 for a married pair. The cost can also be compared favourably with RDC costs.

The simple baggage trailer described in Section 4.16 is estimated to cost $20,000 in a production batch of 20 units.

ITEM	BI-DIRECTIONAL SINGLE UNIT ($000)	BI-DIRECTIONAL* MARRIED PAIR ($000)
Basic coach(es) with 40 seats, DDA 6V-92TA Engine, Allison DDA 740D transmission in road configuration	250	460
Credit for road wheels, axles, brakes, etc. which are not required	(20)	(40)
Second driver's position, including instruments, seats, windshields, defrost/demist, etc.	20	-
Coupling, umbilical and interconnection	-	15
Brakes	5	10
Rail wheels, axles, and gearbox	20	40
Dropbox and reverser	15	30
Suspension subframes	10	20
Special equipment: pilot, lights, horns safety equipment, towbar, etc.	15	25
Conversion labour	20	35
Project management, productionization & tooling cost amortized over 10 married pairs or 20 single units	25	50
TOTAL	360	645

*Note: Second Unit Supplied in Freight Configuration

TABLE 8: PRELIMINARY COST ESTIMATES

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The following conclusions are based on the work performed in Phase I of the program:

- The remote services requirement for a passenger vehicle can be met by a railbus based on the conversion and modification of a conventional intercity highway coach, such as the MCI 102A2, built in Winnipeg, Manitoba.

- There are no technical reasons identified to date that would render infeasible such a conversion.

- The engineering study of a vehicle based on the MCI 102A2 highway coach indicates that the recommended modified vehicle could meet all regulatory requirements existing for conventional rolling stock except those for buff load and conventional coupling.

- Not all of the currently specified equipment such as bells, handholds, etc. should necessarily apply in their entirety to a Railbus product. Some equipment standards should be waived or modified for this vehicle type and application. It is concluded that full public safety could be maintained without some of these requirements for conventional rolling stock.

- A simple suspension design would meet stability requirements but result in a degraded lateral ride with respect to current conventional equipment. The lateral ride would be roughly equivalent, and vertical ride superior to the ride of the current WCSS prototype vehicle. A more sophisticated design with cross-bracing between the single axles would achieve acceptable stability with ride equivalent to conventional equipment in both axes.

- The selected 229 kW (305 HP) Detroit Diesel Allison 6V92-TA engine combined with a 4-speed automatic transmission with lock-up in the top three gears will achieve the required maximum speed and climb a 3% grade at 80 km/h at full accessory load - an improved performance relative to imported vehicles.

- Fuel consumption will be 22.6 l/100 km (12.5 mpg) empty and 23.4 l/100 km (12.1 mpg) fully loaded on typical northern remote services, with average speeds in the 50 to 70 km/h range. This fuel consumption is considerably less than that for conventional equipment or RDCs.

- Tread brakes and actuators are available off-the-shelf for this application and can be activated by the coach air system.

- Vehicle weight empty will increase from the baseline 12,400 kg to 14,500 kg and fully loaded weight from 16,600 kg to 19,000 kg. Weight distribution will be 42.5% on the front axle and 57.5% on the rear axle.

- Wheel sanders will be fitted if proven to be required by operational testing. There is more than adequate space for such an installation.

- The preferred method of obtaining bi-directional operation is to install a second driver position in the rear of the prototype/ preproduction vehicle. For many applications, a back-to-back consist with one unit a freight vehicle is a logical solution. For a single bi-directional unit provision for a baggage trailer is required.

- Production vehicles in small batches of up to 20 units will cost approximately $360,000 for a single bi-directional unit, and $645,000 for a married pair with one being a freight unit. A simple freight trailer for use with the bi-directional single unit would cost approximately $20,000.

- Brake slide protection may not be required but could be fitted based on test results.

- There are applications for up to 20 such units in the remote service field.

7.2 RECOMMENDATIONS

It is recommended that:

- Work proceed immediately in the Phase II program to carry out detail design and construction to meet the design specification of Attachment A-3.

- Suspension design work focus on a cross-braced solution to the stability/ride trade-off issue.

- The preproduction prototype vehicle should be constructed with two driving positions.

Note:

The program has been terminated for convenience by Transport Canada on the understanding that it will remain in abeyance until a decision by Transport Canada is made on the direction Railbus Technology will take in Canada. This decision is currently anticipated to take place in early spring 1987.

8.0 REFERENCES

1) "Proposal for the Design, Construction and Testing of a New Canadian Railbus Vehicle of Advanced Design," TTL Ltd. - November 1985.

2) "A Preliminary Evaluation of a Proposed Railbus Demonstration Project," prepared for Manitoba Department of Highways and Transportation by M. Babulic - March 1983.

3) "Testing of the WCSS Railbus on the INCO Railway Line," prepared for Transportation Development Centre, TP7414E, by J.H. Stannard and H.R. Skoblenick - December 1985.

4) "The Conceptual Design of an Advanced Canadian High Capacity Highway Coach," prepared for Transportation Development Centre, TP6300E, by J.H. Stannard - March 1985.

5) "Maintenance Manual for 102 A2 and 102 A3," Motor Coach Industries, Winnipeg, Manitoba - September 1985.

6) Minutes of Review Session of Phase I Interim Report, TTL Ref. CFD/R&D/9650 by P. Timan - August 1986.

7) "Finite Element Analysis of the Canadian Advanced Railbus Front and Rear Suspension Subframes" prepared for Transportation Technology Ltd. by the Industrial Technology Centre/Manitoba Research Council, Project #06783 - September 1986.

ATTACHMENT A-1

OPERATING AND SERVICE

REQUIREMENTS

OPERATING AND SERVICE REQUIREMENTS FOR ADVANCED RAILBUS

Report No.: 339-511-001

Issue No.: 1

Copy No.:

K.B. for K.B. ARMSTRONG

Originator

Project Engineer

Project Manager

Date: 17 NOV. 1986

Date: 17 Nov. 1986

SUMMARY

This report provides the operating and service requirements needed for successful utilization of the advance Canadian Railbus during revenue service. More specifically, this report provides a general overview of those specific routes that represent primary and secondary applications for potential railbus operations.

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1.0 PURPOSE

The purpose of this report is to identify the major operating requirements to be incorporated into the Canadian Advanced Railbus. In addition, identification of primary rail line applications for railbus service operations is to be provided.

The work was undertaken in accordance with the Detailed Work Plan, as identified in TTL Report No. 339-910-001 (Ref. 1).

2.0 METHODOLOGY

The methodology selected was:

- Consultation with participants from CIGGT, Kingston; VIA Rail, Montreal; CN Rail, Montreal; Canadian Transport Commission, Ottawa; and TDC, Montreal.

- Consultation with subcontractors (CANAC) and information related to alternative transit/railbus technologies.

- Review of correspondence material between CN Rail, VIA Rail, CTC, and TDC related to the railbus concept that involves service and operating criteria.

- Identification of primary railbus service applications on remote service rail lines from information and statistics provided by VIA Rail and CN Rail.

- Review of experience gained during operation of the WCSS prototype Railbus on the INCO and CN railway lines in Thompson, Manitoba.

- Discussions with representatives of the Northern communities of Thompson, Thicket Portage and Pikwitonei, Manitoba.

- Review of Northern remote service requirements with the Manitoba department of Highways and Transportation.

Sections 3, 4 and 5 of this report were prepared with assistance from CIGGT, Kingston under subcontract to TTL.

3.0 BACKGROUND

3.1 GENERAL

Most railway passenger services in Canada are provided by VIA Rail Canada, a federal Crown Corporation. VIA owns, and does much of the maintenance on, its fleet of rolling stock and motive power. VIA also provides the marketing and other on-board services. Operations are undertaken by individual railways (generally CN or CP) under contract to VIA. These railways provide train crews and the required track, and other support services. Stations are operated by both VIA and the carrier.

VIA's operating losses (approximately $400 million in 1985, or 67 percent of total costs) are underwritten by the federal government.

In addition to VIA, CN operates (or until very recently) has operated a few small passenger services on its own. Passenger services are also provided on the provincially-owned British Columbia Railway, the Ontario Northland Railway and on various private railways including the Algoma Central, and the Quebec North Shore and Labrador Railway. Under the provisions of the National Transportation Act, 80 percent of the loss on a number of these services is underwritten by the Federal Government. In addition, commuter rail services are operated by CN and CP in the Montreal and Toronto metropolitan areas under contract to government transportation authorities.

In partial response to the increasing costs to the public treasury of railway passenger services, the government introduced a number of measures in the spring of 1986 in the proposed VIA legislation. Among them is the "use it or lose it" philosophy. Essentially, this would require VIA to meet specific percentages of "avoidable" costs from direct passenger

revenues. Services which do not meet the targets would be curtailed or eliminated.

Revenue targets for trains in the Quebec-Windsor Corridor are proposed to be 100 percent of "avoidable" costs. The target for transcontinental trains is 60 percent, while the target for "regional" trains and some of those classified as "remote" services is 40 percent.

No revenue targets have been established for the true "remote" services, nor is it clear how such services will be handled. These remote services appear to form a "protected" network that will be provided by the government. In 1984, the revenue from remote services covered less than ten percent of fully allocated costs, and contributed $60 million dollars to VIA's losses. This represents 12.5 percent of the total VIA loss on only 7.5 percent of the passenger mile workload.

In addition to providing specific cost/revenue ratio targets, it can be expected that the government will institute some form of formal or informal ceiling on the funds it devotes to railway passenger losses. Thus it cannot be expected that services which simply meet the targets would be expanded, even if the number of passengers served and the level of service increases.

In consequence, the object of various new equipment programmes in the railway passenger sector needs to focus on methods of decreasing costs. In some areas, there may be an opportunity for increasing revenues through higher ridership or fares, and new equipment may contribute to this. In many other areas, especially services which are candidates for railbus technology, such an opportunity is limited.

3.2 THE MARKET FOR RAIL PASSENGER SERVICES

The market for railway passenger service in Canada is stratified into seven different markets. This market segmentation is not absolute and there is a considerable overlap between services in one market and another, and at times it is difficult to assign a given service to a specific market. The seven markets and their main characteristics are as follows:

TRANSCONTINENTAL WEST: Typically long (250-500 seats) trains and long trips (1300-1500 kilometers, 8-72 hours) with a high level of amenities (sleeping cars, loungers, etc.), and one trip per direction each day.

Comfort, price and the "ride experience" are considered to be the prime requisities for these services, although there is a considerable component of short to medium haul intra-regional demand on these services, especially in the off-peak periods.

TRANSCONTINENTAL EAST: Similar to the west, but with slightly shorter trains, much shorter trip duration (no more than 22 hours) and a lower proportion of sleepers to total seats.

Again, the comfort, price and amenities are important market considerations, although the proportion of intra regional and inter-regional pure transportation is probably higher in the east.

LONGHAUL REMOTES: (For example Capreol to Winnipeg). Typically two to three or four (at peak periods) cars, with very low load factors, with less emphasis on amenities, but still with a need for some type of sleeping accommodation and meal services. Trip lengths are up to 1600 kilometers plus, and frequency is two to three per week per direction.

In these markets, comfort is of less concern. Price, frequency and reliability are the key to demand. To a certain extent, however, it is expected that the demand in these markets can be taken somewhat as given.

Another major requirement in these markets is the ability of trains to carry considerable oversized "baggage" such as canoes, snowmobiles, camp supplies, etc., including (although they may not be officially allowed) fuel oil and other dangerous commodities in emergency situations.

QUEBEC-WINDSOR CORRIDOR: These are typically short to medium length (up to 540 kilometers and 4.5 hours) trips with a considerable variation in train size (from 200 to 700 seats depending upon the day of the week and the time of the day). Trains are typically "fast" (up to 145 kph) and there are multiple trips per day.

The key factors of demand in the corridor are trip time, price, comfort, and frequency.

REGIONAL: Typically these are shorter trains (one, two or three cars) involving shorter distances (160-320 kilometers) but longer trip times (up to 5 hours). There are some regional services which are longer (up to 480 kilometers, 6.5 hours); on such runs, there tends to be a smaller proportion of through traffic. Frequencies are generally one or two departures per day. Only coach accommodation is offered, with limited snack-bar service. Only some trains offer checked baggage.

The determining factors of demand are similar to that in the corridor, with a greater emphasis on price and convenience and lesser emphasis on speed and comfort.

REMOTES: These are typically short to medium distance (160 to 480 kilometers) runs operated with one, and occasionally two cars. Seating capacity is usually in the range of 40 to 80, but ridership averages in the two or three to fifteen passenger miles per train mile. There is considerable peaking on some days so that ridership can reach as high as 40 to 80 passengers. Service is typically provided two or three times per week, but with outbound and inbound trips being scheduled on different days. Many of these short-distance remote services are currently operated as mixed-trains, with one passenger car being added to a scheduled freight train.

With the exception of the need for sleeping and meal accommodation, the same determinents of demand apply to the short distance remotes as apply to the Long Haul Remote Market discussed above.

COMMUTER: CN and CP operate commuter trains over their lines in the Montreal and Toronto areas under contract with government agencies. These are typically longer trains (up to 400 seats) with a high frequency of service during peak hours.

3.3 CURRENT EQUIPMENT

VIA currently has a fleet of five hundred or so conventional steel and stainless steel cars built in the early 1950s for CN and CP. These are used in the transcontinental and various other services. These cars are steam-heated and are in what can best be described as "poor" shape. Maintenance costs are relatively high and are tending to increase over time. At the present time negotiation is underway to replace many of these cars with new equipment on transcontinental routes.

VIA also has a fleet of 77 self-propelled Rail Diesel Cars built by Budd in the mid 1950s. These are used mainly on regional services and as enrichments to some of the shorter Corridor services. While old, the RDCs are in "reasonable to good" shape and do not have too many serious problems. VIA is in the process of upgrading the engines and running gear on most of its RDCs which should provide for better performance, availability and reliability and slightly lower maintenance costs. There is considerable operating life left in the RDCs without the need for overly large capital expenditures.

There are 100 new LRC cars (with 30 locomotives) built in the late 1970s and early 1980s by Bombardier. These are used in the corridor. There are still problems with this equipment. Maintenance costs have been higher than expected and availability and reliability lower than is normal for new equipment. Various programmes are under way to correct these defects. It is considered that the LRC fleet has at least 15-20 years of life remaining although the cost of the capital programmes to correct the deficiencies is not known.

There is a handful of older (40 year plus), heavier conventional railcars with self-contained heating systems which are used in mixed train service on a number of the shorter remote services. Many of these cars are combined baggage/coaches. Their condition can be best described as "poor" and it can be expected that major capital maintenance or replacement (by cascading other equipment) will be required in the next few years.

There are various other cars (such as the Tempo) which again are old and in poor shape.

With the exception of the LRC's and a few remanufactured units, VIA's fleet of locomotives is as old and in as poor or worse shape than its cars. Twenty or thirty new 3,000 horsepower locomotives are on order and will replace a number of the existing units. Over the next few years, most of the 1950s vintage locomotives will need to be replaced or remanufactured at a cost of $1.5 to $2.5 million each.

3.4 COST STRUCTURE OF RAILWAY PASSENGER SERVICES

The cost structure of railway passenger services is expected to change somewhat under the provisions of the proposed VIA Rail Act whereby CN and CP are only to be allowed to charge "incremental" costs. The impact of these changes are not fully understood, except that they will tend to decrease the relative importance of roadway useage charges.

The major components of passenger service costs are made up as follows:

ROADWAY USEAGE COSTS: Assessed on the basis of train miles by CN/CP to VIA. These costs are independent of train size and type.

STATION AND OTHER HANDLING COSTS: Partially incurred by VIA directly and partially assessed by CN/CP. These costs vary with traffic density and frequency, however there is a minimum level for the types of services that may be candidates for railbus technologies.

CREW COSTS: Which are payable by VIA to the railways on the basis of costs. The main determinant of this cost is train miles. There can be substantial differences by route or

equipment type (locomotive hauled or self-propelled). Train size has a small impact.

EQUIPMENT MAINTENANCE AND SERVICING: These are partially incurred directly by VIA and partially assessed by the railways. There is a significant fixed cost element. The variable portion varies in part with fleet size, mileage, and days used.

ROADWAY MAINTENANCE: Which is assessed by the railways on the basis of gross train weights.

VIA ADMINISTRATION: Which is allocated to individual services.

EQUIPMENT CAPITAL CHARGES: Which is allocated to individual services.

For a "typical" service that might be a candidate for a railbus technology, operating costs might be on the order of $15-$17 dollars per mile for a 100 seat locomotive-hauled train and $11-$13 using RDCs.

Operations costs might be distributed as follows:

		Locomotive Hauled	RDC
o	Roadway useage fees	19%	23%
o	Roadway maintenance costs	3%	2%
o	Equipment maintenance/servicing	43%	46%
o	Fuel	11%	8%
o	Crew	24%	21%
		100%	100%

These operations costs account for only 65 to 75 percent of total costs allocated to a service.

In the case of mixed trains, costing is complicated. VIA is presently not charged the crew costs, the roadway useage fee or the locomotive portion of roadway maintenance, equipment maintenance and fuel. VIA may pay only 35 to 40 percent of the quoted locomotive-hauled train costs. This method of cost allocation is under appeal by CN.

4.0 COST ADVANTAGES OF RAILBUS VEHICLES

As noted in the section on cost structure above, the application of a railbus technology to existing railway passenger services will have an impact on only a part of the total costs of operations.

FUEL: The reduced weight of the railbus and other considerations will result in savings in fuel costs. Assessing the value of this saving is difficult since existing fuel cost estimates are based on system averages adjusted for vehicle weights and are subject to considerable error, however, present RDC's operate at approximately 4-5 miles per gallon and initial estimates of the Railbus range from 8-12 miles/gallon, representing potentially significant savings, depending upon seating.

ROADWAY MAINTENANCE: The lighter weight of a railbus per seat would translate into potentially large savings in this cost element. The savings would be small in terms of absolute dollars saved and as a proportion of total costs saved.

ROADWAY USEAGE FEES: This cost will not change substantially with the use of a railbus technology.

EQUIPMENT MAINTENANCE: Maintenance requirements per mile for the railbus technology can be expected to be lower than that of existing equipment, partially due to the technology and partially due to the simple fact that the equipment would be new rather than 30 or more years old.

Potentially significant reduction in equipment maintenance costs can also be realized by utilizing local subcontractors. This can be particularly advantageous where the nature of the equipment is primarily automotive with any railway equipment limited to the running gear, thereby minimizing the need for

special training and opening up the market for potential subcontractors to a much wider base.

The decrease in costs would not be as dramatic in practice as might be expected if this type of innovative operating plan is not employed. First, if existing maintenance procedures are retained, there are a number of categories which are generally included in the equipment maintenance classification which would not be affected, such as various cleaning, inspection and servicing activities. Secondly, reduced maintenance requirements do not always translate into reduced costs. Shop overheads and other costs may not change substantially and the reduced maintenance requirements may not be sufficient to actually reduce manpower.

CREW: Crew savings would be substantial when comparing railbuses to locomotive-hauled trains. Under existing Union labour agreements, no substantive savings in crew costs over RDC operations could be gained by the use of a railbus. Innovative changes to these agreements could result in significant crew cost savings for the Railbus. (Crewing considerations are discussed further in a separate Section 5.2).

MARKETING, STATION, ADMINISTRATION COSTS: These costs will not be materially affected by the simple substitution of a railbus technology for a conventional technology. Again, local subcontracts may be a technique to reduce costs in this area.

CAPITAL CHARGES FOR EQUIPMENT: The capital cost of purchasing a new railbus may be higher than the embedded historical costs of continuing to operate existing equipment depending on the type of Railbus technology employed. When compared to the capital costs which may need to be incurred to bring the current equipment to a reasonable standard for continued operation over a long period, it is not clear how the railbus

compares since the actual present state of repair of existing equipment is not clearly defined. The capital charges are probably marginally higher for the railbus. If any substantial replacement/ remanufacturing of conventional equipment must be undertaken, the railbus capital cost will be lower.

RELIABILITY: The reliability and availability of equipment has an impact both on direct costs and on the fleet size required to serve a given market. Such costs are difficult to assess. On net, some advantage should be expected for a new vehicle.

REVENUES: In some cases, a railbus technology could be used to offer an improved level of service than is now offered. This can lead to increased revenues. Little, if any, market research has been done which would allow an evaluation of the potential revenue impact.

SUMMARY: In total terms, a net cost advantage can be expected given the application of a railbus technology in place of existing equipment for small consists. The advantage compared to locomotive hauled trains would be greater than when compared to RDCs. In the special case of mixed trains under the existing costing rules, the railbus would not have a cost advantage. While the cost savings of using a railbus technology on routes presently operated by RDCs may not be overwhelming, especially since many RDCs have been upgraded, the displaced RDCs could be used to replace conventional locomotive-hauled trains in some markets. Thus the true cost comparison for some routes is railbus versus conventional equipment.

5.0 MARKETS FOR RAILBUS VEHICLE

While there appear to be cost advantages to the application of a railbus technology in the Canadian railway passenger sector, not all of the possible markets would be suitable. The matching of the technology to the markets is discussed below.

5.1 REVIEW OF MARKETS BY SECTOR

TRANSCONTINENTAL MARKETS

It is not reasonable to expect that the railbus could be a candidate technology compared to conventional (new or existing) equipment in either of the Eastern or Western Transcontinental markets. The requirements for sleeping and dining accommodation, the higher levels of comfort considered necessary for the long-haul market, and the need to serve many hundred passengers per trip tend to rule out railbus technology.

There may be some market for use of the railbus technology as new supplementary and/or complementary local service running on the same routes as the transcontinental services and feeding them. Such a system might allow a decrease in the number of stations at which long haul trains must stop (decreasing transit time and potentially decreasing costs). It might also allow a reduction in the number of cars on the transcontinental trains. While there is considerable local traffic in some areas on these trains, it is not clear to what extent local traffic contributes to the number of seats that must be provided on the existing trains. At best, only one coach might be dropped in favour of providing local railbus service in some areas.

There are, however, significant cost disadvantages to such a supplemental service strategy. Providing the equivalent of one coach worth of seating using railbus vehicles would require an increase in crew costs and a duplication of the train-mile costs levied by the railways. Neither VIA nor the federal government appears to have seriously considered the supplemental service strategy. Given the apparent thrust of the proposed VIA legistation and the availability of highway services parallel to many of the transcontinental routes, it is unlikely that supplemental services would provide a viable railbus market.

LONG HAUL REMOTE MARKET

The reasons that rule out the use of railbus technology in the transcontinental markets also apply to the Long Haul Remote Market. Again, sleeping and meal accommodations are required on most routes. Since there is a lower availability of highway transport on many of these routes, a low-cost supplemental service may offer more prospects of viability in the remote market than in the transcontinental market. Again, however, there is a cost penalty to increased frequencies which is independent of the vehicle technology. It is unlikely that increased revenues and ridership would be sufficient to justify the added costs.

CORRIDOR

Many of the Quebec-Windsor corridor services are not good candidates for a limited railbus technology since train sizes are generally such that up to 16 individual vehicles would need to be operated as a single train. It should also be noted that the existing LRC fleet, while not without its problems, has considerable life remaining and a non-existent to limited

salvage value. The sunk cost of this equipment, gives little opportunity to save on capital costs. In addition, it has also been noted that there are a number of individual runs in the corridor which would seem to have sufficiently low ridership (three cars with 20 percent load factors) to warrant consideration for a railbus or similar technology. Many of these, however, would not be candidates since the cycling of the existing fleet is highly integrated and since a high peaking capacity must be provided. Replacement with some form of a railbus technology would not significantly reduce the fleet requirements for the existing equipment, but would simply reduce the utilization, without a corresponding reduction in maintenance costs. In addition to these drawbacks, candidate railbus technologies would need to offer a significantly higher operating speed, and comfort level than is now contemplated.

Within the corridor there are some shorter runs, in terms of both distance and required train size, that could be candidates for a modified railbus technology. Many of these runs are now served by RDC equipment, which might be profitably used in other markets. A railbus technology which offered in the 150 seat range with a top speed in the 140 kph range could be a viable alternative. Again comfort and amenities, as compared to existing highway bus services, would be an important determinant of market penetration.

REGIONAL MARKET

The Regional market offers a number of opportunities for a railbus technology. These are currently served mainly by RDCs, but there are a few locomotive-hauled contentional trains. A railbus technology would be a value in these markets, providing that a seating capacity in the range of 100 to 150 is available per consist on a number of routes. There are a few routes

where the 80 seat range would be sufficient. For regional services only limited baggage capacity is required. Full penetration of this market could use 75 or more railbus units.

While the current version of the proposed railbus technology offers some 40 or 80 seats in single or paired operation, there would be little advantage to increasing the frequency on routes where 160 seats are required. The added crew costs and roadway useage charges would be substantially greater than any increased revenue effects of the increased frequency. The demand pattern of many regional services is in to the major centre in the morning and out in the evening. Providing the additional 80 seats in mid-day would not satisfy the existing demand.

Fragmenting the regional market into routes/runs that are amenable to railbus and ones that are not, should also be avoided. Otherwise a certain degree of operational flexibility and savings in maintenance/servicing could be lost. For example a number of regional services are operated out of Halifax using a single RDC pool. If one third of the runs were converted to railbus, the total number of seats in the fleet might need to increase since not all equipment could be dispatched on all routes. In addition, there would be two separate types of equipment to maintain and service instead of one type.

REMOTE (SHORT HAUL) MARKET

The Short Distance Remote Market also offers an opportunity for the railbus technology. As is noted below, however, the absolute size of the market is limited. Existing services might absorb eight to ten units plus additional units for baggage or some form of freight trailer. The reinstatement of recently discontinued remote services might require another ten units.

These services tend to be isolated from one another, so that equipment pooling is not as much of an issue.

The individual components of this market are discussed in detail in Section 7.0 of this report.

PRIVATE LINE/SPECIAL MARKET

There exists strong market possibilities for railbus applications on privately-owned short line railways and other rail-orientated special markets. This market has good potential for configuring railbus design to individual customer requirements.

There are many possible railbus applications in a specialty market. Some of these specialty applications where the ability to be self-propelled is an advantage are:

- Emergency response command/control rail vehicle:
- Maintenance crew/equipment vehicle;
- Mobile medical clinic rail vehicle;
- Track geometry and track inspection vehicle; and
- Short-line railway rail passenger vehicle.

Short-line railways are not required to meet design/operating specifications as set out by regulatory agencies when railbus vehicles are used exclusively on their lines. Railbus passenger operations would be subject to some regulatory requirements, but would be less restrictive than rail passenger equipment that is interchanged between different rail carriers.

Narrow-gauge railway lines would require some vehicle structural design changes in order to safely operate on these tracks.

5.2 THE QUESTION OF CREWING

Under the present institutional structures, there are three distinct groups which make-up train crews, such as engineers, conductors/brakeman, and on-board service (OBS) staff. All are represented by different organizations. Only OBS staff actually are VIA employees. The others are currently employees of the individual operating railway companies. Discussions are under way for a transfer of these employees to VIA.

Under the present collective agreements, there are two engineers assigned on locomotive-hauled trains. (On freight trains, there is only one engineer, but there is one brakemen in the cab with the engineer). Only one engineer is assigned to self-propelled equipment such as the RDC. The reasons for this difference are not well-documented, but harken back to a 1930 master labour agreement and is connected with the fireman issue. There is also a contribution by the applicable technology. In self-propelled equipment, the engineer is not isolated from the rest of the crew, so is not working alone. In a locomotive (especially the steam locomotives used at the time of the master agreement), the engineer is cut off from the rest of the train crew.

There should be no changes due to use of a railbus technology in the assignment of engineers. One engineer would be assigned to any railbus consist.

The current agreements assign one conductor for a single RDC consist, and add a brakeman with a second RDC unit and a second brakeman after two units. Again, no change should be expected as the result of using a railbus technology. The only question is what would constitute a single unit. It is reasonable to expect that a two railbus unit offering the similar number of

seats as a single RDC unit would be treated as a single unit for purposes of crew assignment. There is no guarantee that such a practice would be followed, however negotiations would have to be carefully undertaken.

OBS staff are assigned by VIA as required. For routes that are railbus candidates, often no OBS service is offered. In any event, there is considerable flexibility in OBS assignment that would not be affected by the choice of technology.

Considerable attention has been given in other investigations to the design of a railbus that could be operated with a one man crew. Given the current climate, it is unlikely that single-person train crews will be acceptable to government, labour organizations or railways within the near future. It should be noted that CN and CP do not allow even hi-rail vehicles to be operated on track with a single person in the vehicle.

There are also a number of operational reasons for the use of more than single-person crews. These are especially applicable to many of the lines on which the railbus would be a viable candidate.

In many circumstances, even on rail lines with Centralized Traffic Control and movement by signal indication, train orders are transmitted by radio. Until automatic train control and other advanced systems are introduced, the operational rules presently require that these orders be heard by at least two members of a train crew who confirm the orders between themselves, and the orders are reported back to the train dispatches.

When signals are inoperable or where there is a problem on non-signalled lines, a minimum of two crew members are presently required for train protection (flagging). This

operation is particularly awkward and perhaps some innovative rethinking of this procedure could make it more safety functional for both the crew and the railroads. However, any changes in this area must be made across the entire system.

There are a number of routes with neither power-operated turnouts nor switch tenders. On these rail lines, train crews are responsible for lining switches. While presently two crew members can quickly line switches and operate the vehicle, these operations could potentially be performed by a single crew member.

There are various other initiatives which might be undertaken on the crewing side that could effect substantial cost savings. In a casual sense, such initiatives could not be attributed to the substitution of a railbus technology for conventional equipment. The introduction of a new railbus technology might, however, be a convenient forum under which such initiatives may be introduced. Among such initiatives are: movement from payment by the mile to payment by the hour or day, rationalization of crew districts, and rationalization of craft ownership of specific tasks. For example, there would be a substantial advantage if duties currently carried out by CN/CP brakemen/ conductors and VIA OBS staff could be carried out by the same person on short trains.

Automatic Train Control and other advanced command and control systems that are now being investigated by the North American rail industry could provide an alternate method of ensuring train protection and transmission of instructions allowing exploitation of the smaller operating crews on railbus technologies. Indeed, AMTRAK has recently negotiated a time-based crew payment scheme, independent of Automatic Train Control.

5.3 IMPLICATIONS FOR VEHICLE DESIGN

A review of the market characteristics and of some of the individual candidate routes (including discussions with VIA operational personnel) has revealed that the following characteristics are necessary or desirable for a railbus.

OPERATING RANGE

The vehicle should be able to be dispatched from its home terminal to its away terminal, layover, and return without scheduled servicing (including fueling). At a number of away terminals, there are simply no servicing facilities. In addition, some savings can be made in not having to provide as many small-scale servicing facilities. The normal range would be about 650 km total for routes which are candidates for the railbus. There are some, where the required range would be 1000 km. Increasing the range so that more than one round trip can be made would have definite cost advantages.

In determining fuel tank capacity, provision for engine idling and auxiliary heating during layovers (if necessary) should be made as well as provision for maintaining power and heat during on-line delays.

OPERATING SPEED

Although many of the candidate routes are not currently operated at average speeds in excess of 50 to 80 kph, trains should have the ability to cruise at a minimum of 100 kph in order to makeup time. In addition, a number of routes operate partially over higher-speed mainlines, where the ability to keep up with the flow of traffic is necessary.

For some regional lines and supplementary corridor services, a top speed approaching 145 kph would be useful for marketing reasons and to keep up with the flow of passenger traffic.

RAILBUS SEATING CAPACITY

Seating capacity requirements are definitely stratified by market segments. For remote service, some trains in the 20 seat range would be sufficient, others would need to be in the 35-45 seat range.

For the regional services, minimum seating is in the 80 seat per train range. Most trains would require 120-160 seats per train. A few would require seating in the range of 200.

For corridor applications, a range of 150-200 seats per train would be required.

These potential capacities may seem at odds with the reported statistics of an average passenger miles per train mile of three and 15 and 30-40. These statistics mask both seasonal demand peaking and the fact that many trains leave a remote terminal practically empty, but arrive in a major centre with a considerable load. An average demand of 15 passenger miles per train mile would be consistent with 30 or more passengers miles per train mile at peak periods, or with a 30 passengers being carried at some point on an "average" trip.

MULTIPLE UNIT/FIXED CONSIST OPERATION

Multiple unit operation would be of value, in making up long consists for application in other than remote markets. With fixed consists, there would be a cost penalty for the longer

trains since a number of vehicles would have to be taken out of service when one vehicle requires maintenance.

Reconfiguring consists for multiple unit operations need not be an easy field operation. If it takes an hour or two in a maintenance facility this would be sufficient.

For longer train multiple-unit operation, there should be access to all sections of the train. If this is not possible, added crew costs can be expected, since it could be expected that a crew member should be in each section of the train.

For some VIA applications, a varient of MU operations, the J-Train operation would be of value. This involves running two separate trains, each with its own crew, as a single train over some parts of a route. Access between the two trains would not be necessary. J-Trains are only applicable in regional and corridor applications.

ENTRY DOORS

At least one set of vehicle functional requirements has suggested that a single entry door on one side would be acceptable. For corridor and regional services, and even a number of remote ones, this may be too restrictive. On a given line, not all stations are on the same side. Often the door side might end up between two tracks. The safety and operational flexibility implications of a single side door would require additional operational procedures.

BAGGAGE

As with seating capacity, this requirement is stratified by market segment. For corridor and most regional applications, baggage racks plus bus style cargo bays under the deck will provide sufficient space. Checked baggage is generally not offered on these trains. The design of cargo bays and baggage racks should be sufficient to accommodate long, large items.

For the remote service application, considerable capacity to carry oversize "baggage" is a necessity. Part of the justification for incurring the losses on such services is the social need to provide low-cost, reliable, all-weather public transportation to areas not served by highway. If the people are to be moved, it is also necessary to move their goods. Typical of the baggage that must be handled are canoes, snowmobiles, oil drums and so on. The extent of the freight area required is not clear. Obviously it would not be necessary to provide room for 30 snowmobiles in a 30 seat train, but taking two or three at a time may be necessary.

FOOD/BEVERAGE SERVICES

Provision for a small galley (microwave, coffee pot, fridge and food storage area) should be made. Galleys need not be installed on each vehicle in a consist, or on particular trains.

HANDICAPPED ACCESS

For the regional and corridor markets, easy handicapped access is considered desirable, and perhaps necessary. It is not clear whether this will be a mandatory requirement.

6.0 OPERATING REQUIREMENTS

This section outlines the general requirements for operating, safety, and performance criteria that should be incorporated into the design of a Railbus.

6.1 GENERAL REQUIREMENTS

The railbus should have a minimum seating capacity of 40 passengers. Provision should be made for optional railbus freight capacity in terms of a baggage trailer or equivalent and should be no less than 60 cubic metres, and no less than 6 metres in length (i.e., sufficient length to handle a freight canoe).

Interior features of the railbus are standard HVAC capabilities and an auxiliary heating system, with overhead baggage racks. A unisex washroom should be installed, which is equipped with a chemical toilet, wash basin, and holding tank.

The railbus freight area should have adequate access to permit efficient handling of freight/baggage. The enclosed freight areas should be capable of handling snowmobiles, canoes, stoves, and other non-perishable supplies. The centre of gravity should be as low to ATR level as possible.

Sanders and an adequate sandbox capacity should be installed for assisting traction efforts, when required. Lifting eyes and jacking pad for recovery purposes should be installed.

A single passenger entry/exit door on one side of the railbus should be provided on the railbus vehicle.

6.2 SAFETY REQUIREMENTS

The railbus should be equipped with a driver's console that has the necessary controls to operate the vehicle systems safely and efficiently.

The vehicle should be so designed as to meet all relevant Canadian Motor Vehicle Safety Standards (CMVSS) standards as well as CTC and railway specifications or regulations governing safety as outlined in the Regulatory Requirement TTL report number 339-512-001 (Reference 6). Those areas where exceptions are requested for the railbus vehicle are also outlined in the above referenced report.

An emergency heating system on the railbus, should be capable of maintaining a 10°C interior temperature, with the engine stopped for a minimum of 24 hours, while the outside ambient temperature is -40°C, and wind velocity is 50 kph.

Service brakes should be capable of stopping a fully loaded vehicle, travelling at 48 km/hr within 120 m (400 feet) and in not more than 13.5 seconds.

The parking brake should have sufficient capacity to indefinitely hold a fully loaded vehicle on a 5% grade.

6.3 PERFORMANCE REQUIREMENTS

The railbus should be capable of operating at sustained speeds of 100 km/hour or better, and be able to operate with an outside temperature range of -45°C to +38°C. The minimum operating range of the railbus should be no less than 1000 kilometers.

A snow plow pilot should be standard equipment on the leading end of the railbus. The railbus should be able to operate safely and efficiently when 76 mm ATR snow conditions are present. The snow plow pilot should be so designed as to safely plow out compacted snow banks at public rail crossings.

The railbus should at least be equipped with a removable towbar having a coupler centre line of 34.5 inches ATR and be able to be safely coupled to standard rail equipment.

Axle loadings should not exceed existing railroad limits and AAR specification railway clearances for passenger equipment should not be exceeded.

The railbus should be so designed as to safely negotiate a 23 degree (76 metre) horizontal curve and a 152 metres vertical curve. The railbus should meet AAR rail specification mechanical clearances and operate safely on standard gauge track.

7.0 SERVICE REQUIREMENTS

There are several specific railway lines in Canada which represent primary applications for railbus operations. These rail lines are located in remote areas and are currently served by conventional rail passenger equipment or by mixed freight/passenger trains. In each case, these existing rail services are characterized by relatively low ridership over short to medium distances, with infrequent service in each direction.

7.1 PRIMARY RAIL LINES

The remote services listed below are those railway lines with existing rail passenger services that qualify for railbus operations. They are:

Carrier/Route	Train	Service	Distance
CN Senneterre-Cochrane	Psgr	3/week	184 miles
CN The Pas-Lynn Lake	Mixed	3/week	242 miles
CN Wabowden-Gillam	Mixed	1/week	190 miles
CN Gillam-Churchill	Mixed	1/week	184 miles
CN LacLaBiche-Waterways	Mixed	2/week	172 miles

With the exception of The Pas-Lynn Lake mixed passenger service, the other railway lines can be adequately served by one or two 40 seat capacity railbus vehicles. The existing The Pas-Lynn Lake service utilizes two passenger coaches in order to satisfy a heavier passenger demand on certain days of the week. Therefore, a railbus operation must provide more frequent service than presently exists.

7.2 SECONDARY RAIL LINES

There are other rail lines in Canada which represent secondary applications for railbus operations, but have no current rail passenger service. These rail lines had conventional or mixed passenger service, but service was discontinued due to high operating costs and little or no ridership.

The rail lines listed below are those remote service rail lines without current passenger service that could qualify for railbus operations. They are:

Carrier/Route	Track-class	Distance
CN St. Johns-Carbonear	2	80 miles
CN St. Johns-Argentia	2	84 miles
CN Bishops Falls-Corner Brook	2	138 miles
CN Clarenville-Bonavista	2	89 miles
CN Hearst-Nakina	2	144 miles
CN Sioux Lookout-Thunder Bay	3	202 miles

The Newfoundland CN rail lines are 3 foot 6 inch track gauge, instead of the standard 4 feet 8½ inches. Previous rail passenger service was primarily mixed passenger/freight trains operating one to three days per week in each direction. Freight train tonnages and required line switching affected passenger schedules, thereby making the service unreliable.

7.3 TERTIARY RAIL LINES

Other possible applications for railbus operations are those tertiary rail lines which could qualify, due to remote locations and limited ridership demand.

The routes listed below are those rail lines which represent possible applications for railbus operations. They are:

Carrier	Route	Track-Class
ONR	Cochrane-Moosonee, Ontario	2
Alaska RR	Anchorage-Fairbanks, Alaska	2
Algoma Central	SS Marie-Hearst, Ontario	2
CP Rail	Victoria-Courtenay, BC	2
CP Rail	Toronto-Havelock, Ontario	3
CP Rail	Sudbury-White River, Ontario	4

Depending upon final outcome of federal government hearings and studies, the White Pass & Yukon Railway and the QNSL Railway in Quebec are additional possibilities. Both rail lines are currently shut down or operating infrequently, but represent additional possible applications for railbus operations.

7.4 DETAILED RAILBUS SERVICE OPERATIONS

This section provides a more detailed overview of those primary application rail lines qualifying for railbus service operations. These primary rail lines, as outlined in Section 7.1, are all remote service rail lines. Refer to the service location maps in Appendix A.

SENNETERRE-COCHRANE

The 184 miles between Senneterre, Quebec and Cochrane, Ontario forms the CN Tashereau Subdivision. The rail line is a non-signalled single track controlled by train order authority from Montreal. Freight train traffic on this subdivision averages less than three trains per day.

FRA Track Safety Standards are used to classify track conditions on the Taschereau Subdivision as follows:

Line Location	Rail Size	Class	Psgr Speed
Senneterre-MP 4.0	100-lb	1	15 mph
MP 4.0-MP 22.0	100-lb	3	50 mph
MP 220-MP 166.0	100-lb	2	40 mph
MP 166.0-Cochrane	85-lb	2	30 mph

Current rail passenger service on this route are three VIA trains per week in each direction. Train schedules are tailored to accommodate Montreal passengers travelling to and from some two dozen lodges located east of Senneterre, where passenger demand is high on Fridays/Sundays. Average speed between Senneterre and Cochrane is approximately 35 miles per hour. Within the 184 miles, there are three regular stops and eight flag stops at intermediate stations.

There are 15 sidings on the Taschereau Subdivision for the meeting and passing of trains. The sidings are located every 7 to 16 miles apart and average 2600 feet in length. Wye tracks are located at Cochrane and Senneterre.

Railbus service operations for the Tashereau Subdivision will consist of two 40 seat capacity railbus vehicles. This equipment will provide rail service four days per week in each direction, instead of three trips per week currently provided by VIA Rail.

Connections can be made with VIA Rail trains at Senneterre and ONR trains at Cochrane, which will improve existing connections or provide connections where none previously existed. Railbus

schedules can easily be tailored for daylight operations, due to current VIA Rail/ONR train connection times.

Two railbus vehicles on this service allows provision for spare equipment and also permits adequate maintenance time between trips.

THE PAS-LYNN LAKE

The rail line between The Pas and Lynn Lake in northwestern Manitoba is some 242 miles long. The rail line is a non-signalled, MBS-territory single track controlled from Winnipeg. Freight train traffic averages less than three trains per day on the southern portion, decreasing to less than one train per day on the northern portion.

FRA Track Safety Standards are used to classify track conditions on the Flin Flon and Sherridon Subdivisions as follows:

Line Location	Rail Size	Class	Psgr. Speed
The Pas-Sheridon	100-lb	3	40 mph
Sherridon-MP 111.0	100-lb	1	20 mph
MP 111.0-Lynn Lake	100-lb	2	25 mph

Current rail passenger service is comprised of two mixed passenger/freight trains per week in each direction (VIA coaches on CN freight trains) and one passenger train per week in each direction. Average train speed is less than 25 miles per hour. Depending on freight train tonnage and required train switching, mixed train schedules can be affected.

Sidings are located every 9 to 24 miles for the meeting and passing of trains, and average 1200 feet in length. Due to long distances between some sidings, train delays can be excessive. Wye tracks are located at Lynn Lake, Sherridon, Sherritt Junction, and The Pas.

Railbus service operations for this route will be comprised of two 40 seat railbus vehicles. This equipment will operate four or five days per week in either direction, depending on the time of year. The railbus service will provide increased service frequency compared with existing services.

Railbus connections can be made with other passenger services at the Pas. Due to the 242 mile distance and slow speeds on some portions of the rail line, railbus schedules may require some early evening operation on both ends of the route. Recovery of failed equipment is a major factor.

Two railbus vehicles will provide spare equipment as well as recovery vehicle capability for this route and allow adequate maintenance time between trips.

WABOWDEN-GILLAM

The CN Thicket Subdivision between Wabowden and Gillam, Manitoba forms part of the The Pas-Churchill main line. The distance between the two points is 190 miles. A 30 mile branch line runs north to Thompson, the major commercial centre for northern Manitoba.

The rail lines are non-signalled, MBS-territory single track controlled from Winnipeg. Freight train traffic averages less than one train per day, but increases to two trains per day when Churchill grain trains operate during the summer months.

FRA Track Safety standards are used to classify track conditions on the Thicket and Thompson Subdivision are as follows:

Line Location	Rail Size	Class	Psgr Speed
Wabowden-Odhill	100 lb	3	50 mph
Odhill-Thompson Jct	115 lb	3	40 mph
Thompson Jct-Gillam	100 lb	3	40 mph
Thompson Subdivision	100 lb	2	30 mph

Current rail passenger service on this section consists of three VIA Rail passenger trains per week in each direction. These trains operate to Thompson in each direction. Average train speed is approximately 32 miles per hour. A mixed freight/passenger train operates once per week in each direction between Wabowden and Gillam only.

Sidings are located every 6 to 16 miles for the meeting and passing of trains and average 1900 feet in length. Wye tracks are located at Wabowden, Thompson Junction, Gillam and Thompson.

Railbus service operations for this section will be based on two 40 seat capacity railbus vehicles. This equipment will operate four days per week in each direction from Thompson, and tailored to augment existing VIA Rail passenger service. The railbus service will provide increased service frequency than now currently exists.

Railbus operations could be arranged to serve Gillam-Ilford-Pikwitonei-Thompson on a through schedule. Wabowden-Thicket-Portage-Thompson service could also operate as a through schedule. Great flexibility exists for other service

scheduling, but railbus schedules may require some night operation at both ends of the section. Recovery of failed equipment is a major factor.

Two railbus vehicles will provide spare equipment as well as recovery vehicle capability for this section and will also permit adequate maintenance time between trips.

GILLAM-CHURCHILL

The CN Herchmer Subdivision between Gillam and Churchill, Manitoba is 184 miles long, and is part of the main line from The Pas. This rail line is a non-signalled, MBS territory single track controlled from Winnipeg.

Freight train traffic is very light - less than two trains per week during periods when Churchill grain trains are not operating. FRA Track Safety Standards are used to classify this line as follows:

Line Location	Rail Size	Class	Psgr Speed
Gillam-Weir River	100 lb	2	30 mph
Weir River-Herchmer	85 lb	2	30 mph
Herchmer-Churchill	100 lb	2	30 mph

Current rail passenger service on the Herchmer Subdivision are three VIA Rail passenger trains per week in each direction. Average train speed is approximately 28 miles per hour. A mixed freight/passenger train operates once per week in each direction on alternate days between Gillam and Churchill.

Sidings are located every 5 to 11 miles for the meeting and passing of trains. These sidings average 2000 feet in length. Wye tracks are located almost mid-point at Herchmer, and also at Gillam and Churchill.

Railbus service operations for the Herchmer Subdivision will consist of two 40 seat capacity railbus vehicles. This equipment will provide rail service four days per week in each direction, with more convenient scheduling than presently exists. Other methods of service can be implemented with little difficulty.

Due to the remoteness of this rail line and unavailability of motive power, recovery of failed equipment is a factor. Railbus schedules will provide daylight operation in all cases. Gillam can be a transfer point for railbus vehicles operating to and from Thompson.

Scheduled maintenance at a central location for Thompson and Gillam railbus vehicles is very feasible. Two railbus vehicles on this service allows provision for spare equipment as well as recovery vehicle capability and adequate maintenance time between trips.

LAC LA BICHE-WATERWAYS

The CN Waterways Subdivision between Lac La Biche and Waterways, Alberta is 172 miles long. Waterways is on the outskirts of Fort McMurray, the major commercial centre for northeastern Alberta. The rail line is a non-signalled, MBS-territory single track controlled from Edmonton.

Freight train traffic on this line averages four trains per week. FRA Track Safety Standards are used to classify track conditions on the Waterways Subdivision as follows:

Line Location	Rail Size	Class	Psgr. Speed
Lac La Biche-Leismer	85 lb	2	30 mph
Leismer-MP 223.0	85 lb	2	25 mph
MP 223.0-Lynton	100 lb	2	30 mph
Lynton-Draper	85 lb	1	20 mph
Draper-Waterways	85 lb	2	30 mph

Current rail passenger service on the Waterways Subdivision consists of two CN mixed freight/passenger trains per week in each direction. Average train speed is less than 25 miles per hour. Depending on freight train tonnage and required train switching, mixed train schedules can be affected.

Sidings are located every 7 to 14 miles for the meeting and passing of trains. These sidings average 1500 feet in length. Wye tracks are located at Lac La Biche and Waterways.

Railbus service for this route will be one 40 seat railbus vehicle. This equipment will operate three days per week in each direction. The railbus service will provide increased frequency than now presently exists.

Railbus connections can be made at Lac La Biche with scheduled highway bus service. Railbus schedules will easily permit daylight operation in both directions. Due to remoteness, recovery of failed equipment is a factor.

One railbus vehicle on this service still allows adequate provision for proper maintenance time between trips.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Three potential applications for Railbus service are evident from this study:

- o Regional Service
- o Remote Service
- o Private Line/Special Market

These markets can be further integrated to reveal two distinct operating requirements which are summarized in Table 1.

It is clear from Table 1 that the two distinct operating requirements define two quite different vehicles. A Railbus which meets the requirements for Regional Service can effectively be provided by lightweight rail vehicle technology with buff capability provided by a reinforced bus structure or independent subframe structure.

The less severe requirements of the Remote/Private Line Service can effectively be provided by a much lighter vehicle (low buff capability) with more emphasis on much less expensive, proven automotive bus technology and with minimum modifications to the existing structure. In both cases, minimized capital and operating costs is essential, particularly on the Remote/Private lines since ridership alone on these lines would not justify the expenditures required by the existing equipment and operating environment. On those lines where ridership is low but a pair of vehicles are required for redundancy/ reliability, the lighter minimum change bus technology significantly reduces capital costs.

TABLE 1

POTENTIAL RAILBUS APPLICATION CHARACTERISTICS

Characteristics	Remote/Private Service	Regional Service
Seating Capacity	o Most applications can be serviced by a 40 seat capacity vehicle. o Several applications would benefit from paired vehicle operation for redundancy and reliability but not required as far as seating capacity is concerned.	o Minimum seating for 80, but most trains would require 120-160 seats with some as high as 200.
Range	o Not less than 1000 km plus delay/failure related idle time. o Longer ranges would be of benefit. o Light weight is significant.	o Not less than 1000 km plus delay related idle time. o Light weight is significant.
Speed	o 50 to 80 kph normal operating speeds with ability to cruise at 100 kph.	o 100 to 115 kph normal operating speeds with ability to cruise at 145 kph on certain routes.
Multiple Unit Operation	o Not required o A single two vehicle unit meets most requirements.	o MU operation is a definite requirement to meet train capacities. o Consists of more than two vehicles should be able to be coupled /uncoupled requiring buff load capability.
Baggage	o Oversized baggage capacity is a must. o Typical baggage may include canoes, snowmobiles, food supplies, oil drums, etc.	o Overhead baggage racks plus underfloor or equivalent storage for larger pieces of luggage.

TABLE 1 (Cont'd)

POTENTIAL RAILBUS APPLICATION CHARACTERISTICS

Characteristic	Remote/Private Service	Regional Service
Food Services	o Require Provision for small galley with hot and cold food services on several lines.	o Coffee/cold drinks and snacks on some vehicles.
Entry Doors	o Single passenger door only required on most lines.	o Multiple passenger entry door access is beneficial.
Handicapped Access	o Provision for access required but incorporation may only be on some vehicles; may be offered as an option.	o Handicapped access likely to be required on sufficient number of vehicles.
Maintenance	o Ideal application for subcontracted maintenance. o Should be very reliable since vehicle recovery can be very costly and difficult. o Cannot require servicing in specialized maintenance facility. Such facilities are not located near most remote services.	o Since Regional Markets are close to existing maintenance facilities and since quantities are relatively large, use of existing railway maintenance facilities may be best although subcontracting of cleaning may be advantageous.
Estimated Market	20 single vehicles including trailers plus an unknown speciality market.	Equivalent to 60-80 single vehicles.

It should be noted that both types of Railbus vehicle would benefit greatly if changes to CTC regulatory requirements are made in the long run in order to effectively take advantage of the cost savings potential.

A key element in obtaining these savings for both Railbuses lies in the ability to allow reduced buff load capability. This does not take away from the potential for significant savings in operating and capital cost which can be made by using the new technology of the Railbus as a forum for initiating regulatory changes.

The Railbus defined by the Regional Service could of course meet all of the technical requirements for the Remote/Private Lines Services, but this would inevitably result in much higher capital and operating costs. Arguments for utilizing a single type of Railbus vehicle to operate on all services in order to provide commonality of spare parts and a better bargaining position when purchasing equipment are valid when both types of service operate from a central hub. In remote/private services, however, these factors do not apply and any gains made by increasing the order quantity of the more costly regional railbus would be far outweighed by the savings in capital and operating costs of a minimum change automotive based Railbus.

8.2 RECOMMENDATIONS

With respect to acceptance of this type of new Railbus technology, a survey of customer acceptance would be required. In the remote service applications experience with the testing of the WCSS Railbus has shown excellent public acceptance, and it is anticipated that a trial passenger service run would show positive feed back. In the Regional markets, however,

comparisons with the highway coach may make acceptance of Railbus technology less than desired. More attention to comfort and service frequency may be required in these markets.

Baggage capacity requirements for remote services should be verified by a survey of present usage and anticipated potential requirements.

9.0 REFERENCES

1. TTL Report No. 339-910-001, "Detailed Work Plan For The Design and Development of The Canadian Advanced Railbus".

2. CN Rail Prairie Region Time Table, June 1985.

3. Canadian Trackside Guide 1986 Edition, Bytown Railway Society.

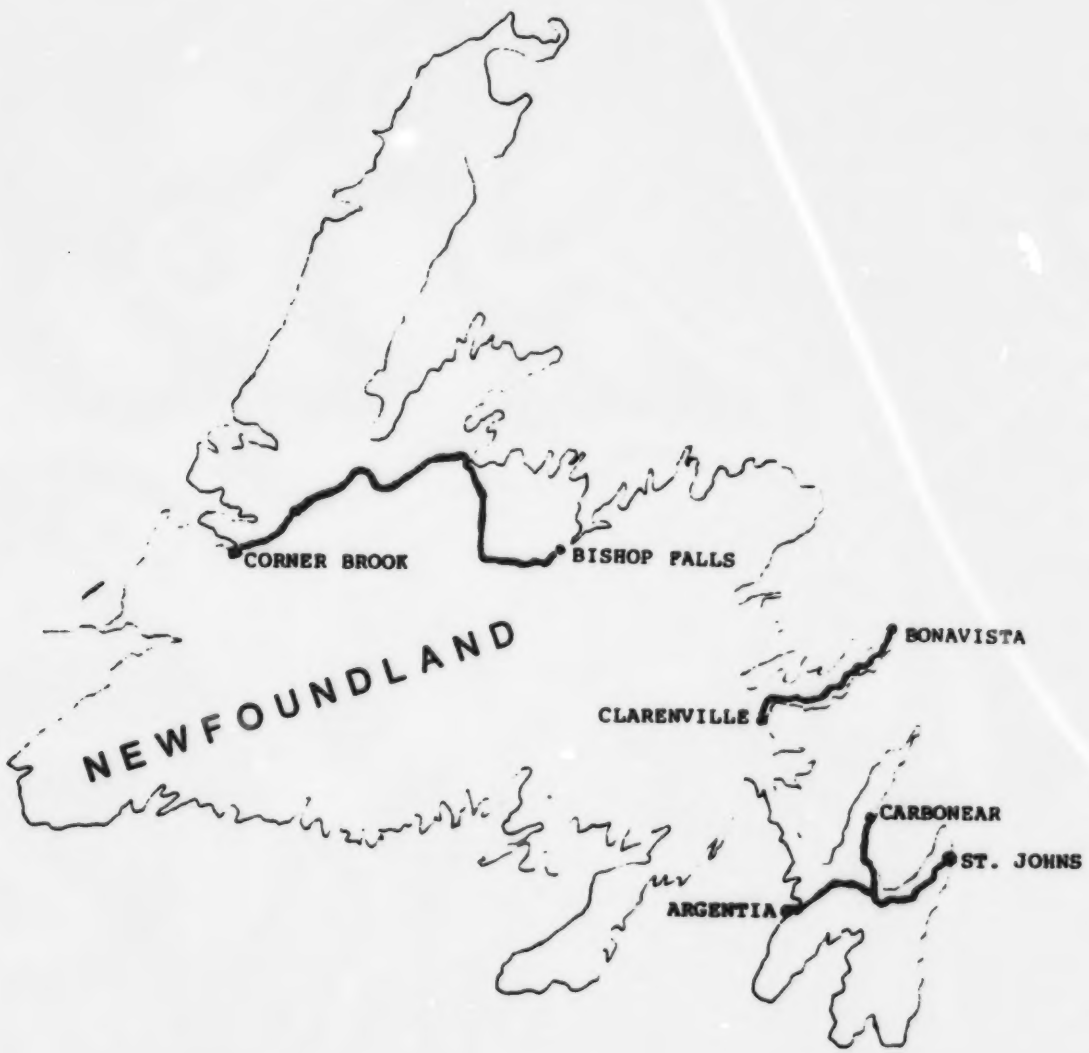
4. Railbus Technology and Market Assessment CIGGT, Kingston, Transport Canada Report No. TP 7007 E.

5. TTL Report No. 338-650-002, "Operational Strategies for Passenger Service Demonstration".

6. TTL Report No. 339-512-001 "Regulatory Requirements".

APPENDIX A

SERVICE LOCATION MAPS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NEWFOUNDLAND
BONAVISTA
CLARENVILLE
CARBONEAR
ST. JOHNS
ARGENTIA

ONTARIO
NAKINA
SIOUX LOOKOUT
HEARST
WHITE RIVER
THUNDER BAY
SUDBURY
SAULT STE. MARIE

GILLAM - THOMPSON - WABOWDEN - CHURCHILL

THE PAS - LYNN LAKE, MANITOBA

LAC LA BICHE - WATERWAYS, ALBERTA

APPENDIX B

CONDENSED FRA TRACK SAFETY STANDARDS

TABLE 1: CONDENSED FRA TRACK SAFETY STANDARDS FOR TANGENT TRACK

Parameters	CLASS OF TRACK					
	1	2	3	4	5	6
Operating Speed Limits						
Freight	10 mph	25 mph	40 mph	60 mph	80 mph	110 mph
Passenger	15 mph	30 mph	60 mph	80 mph	90 mph	110 mph
Gage						
At least	4'8"	4'8"	4'8"	4'8"	4'8"	4'8"
But not more than	4'9¾"	4'9½"	4'9½"	4'9¼"	4'9"	4'8¾"
Alignment						
Deviation of mid offset of 62 ft line not more than	5"	3"	1¾"	1¼"	¾"	½"
Track Surface						
Deviation from uniform profile, either rail, midordinate of 62 ft chord not more than	3"	2¾"	2¼"	2"	1¼"	½"
Deviation from zero cross level at any point on tangent not more than	3"	2"	1¾"	1¼"	1"	½"
Difference in cross level between any two points less than 62 ft apart on tangents not more than	3"	2"	1¾"	1¼"	1"	5/8"

TABLE 2: CONDENSED FRA TRACK SAFETY STANDARDS FOR CURVED TRACK

Parameters	CLASS OF TRACK					
	1	2	3	4	5	6
Operating Speed Limits						
Freight	10 mph	25 mph	40 mph	60 mph	80 mph	110 mph
Passenger	15 mph	30 mph	60 mph	80 mph	90 mph	110 mph
Gage						
At least	4'8"	4'8"	4'8"	4'8"	4'8"	4'8"
But not more than	4'9½"	4'9½"	4'9½"	4'9½"	4'9½"	4'9"
Alignment						
Deviation of midordinate of 62 ft chord not more than	5"	3"	1½"	1¼"	5/8"	3/8"
Track Surface						
Run off in any 31 ft of rail at end of a raise not more than	3¼"	3"	2"	1¼"	1"	¼"
Deviation from designated elevation on spirals not more than	1½"	1¼"	1¼"	1"	¾"	¼"
Variation in cross level on spirals in any 31 ft not more than	2"	1¾"	1¼"	1"	¾"	¼"
Deviation from zero cross level at any point from designated elevation on curves between spirals not more than	3"	2"	1½"	1¼"	1"	5/8"
Difference in cross level between any two points less than 62 ft apart on curves between spirals not more than	3"	2"	1½"	1¼"	1"	5/8"

K6-10491

ATTACHMENT A-2

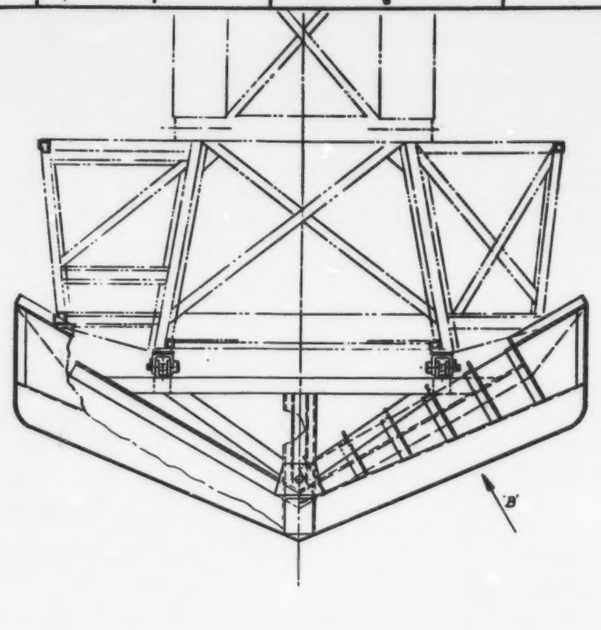
PRELIMINARY DESIGN

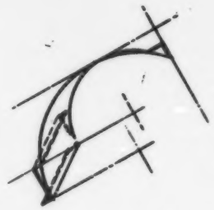
DRAWINGS

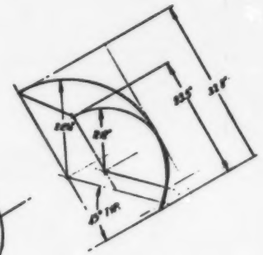
ATTACHMENT A-2

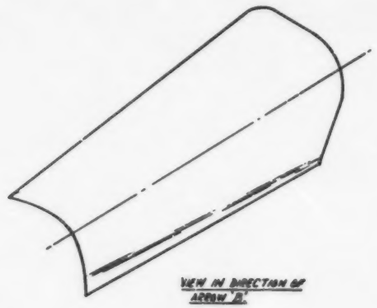
LISTING

E339-110-004	Snow-Plow
E339-110-005	Preliminary Design of Rear Suspension Box Frame
E339-110-008	2-Position Driver Railbus
E339-110-009	Knorr Tread Brake Layout (2 Sheets)
E339-110-010	Drive Train Envelope - Existing Two-Axle Engine Position (Sheet 1 only)
E339-110-011	Preliminary Design of Front Suspension Box Frame
E339-110-012	Preliminary Design of Removable Rear Tow Hitch
E339-110-013	Straight Positioned Engine Proposed Propulsion Layout (2 Sheets)
C339-110-014	Proposed Anti-Roll Bar Location and Modification (Sheet 2 only)
C339-110-016	Exterior Light and Horn Arrangement on Railbus
C339-110-017	Proposed Auxiliary Suspension Reservoir Locations
D339-110-018	Proposed Modification to the Airline Diagram









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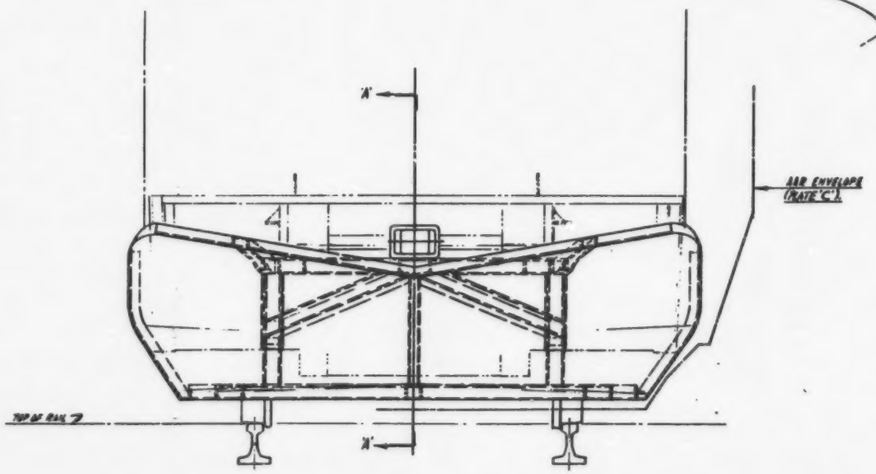

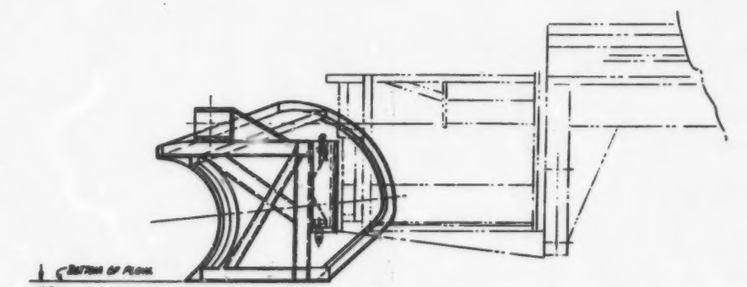

SECTION 'A-A'

NOTES:

FOR FURTHER DESIGN INFORMATION SEE DWG. 539-110-003

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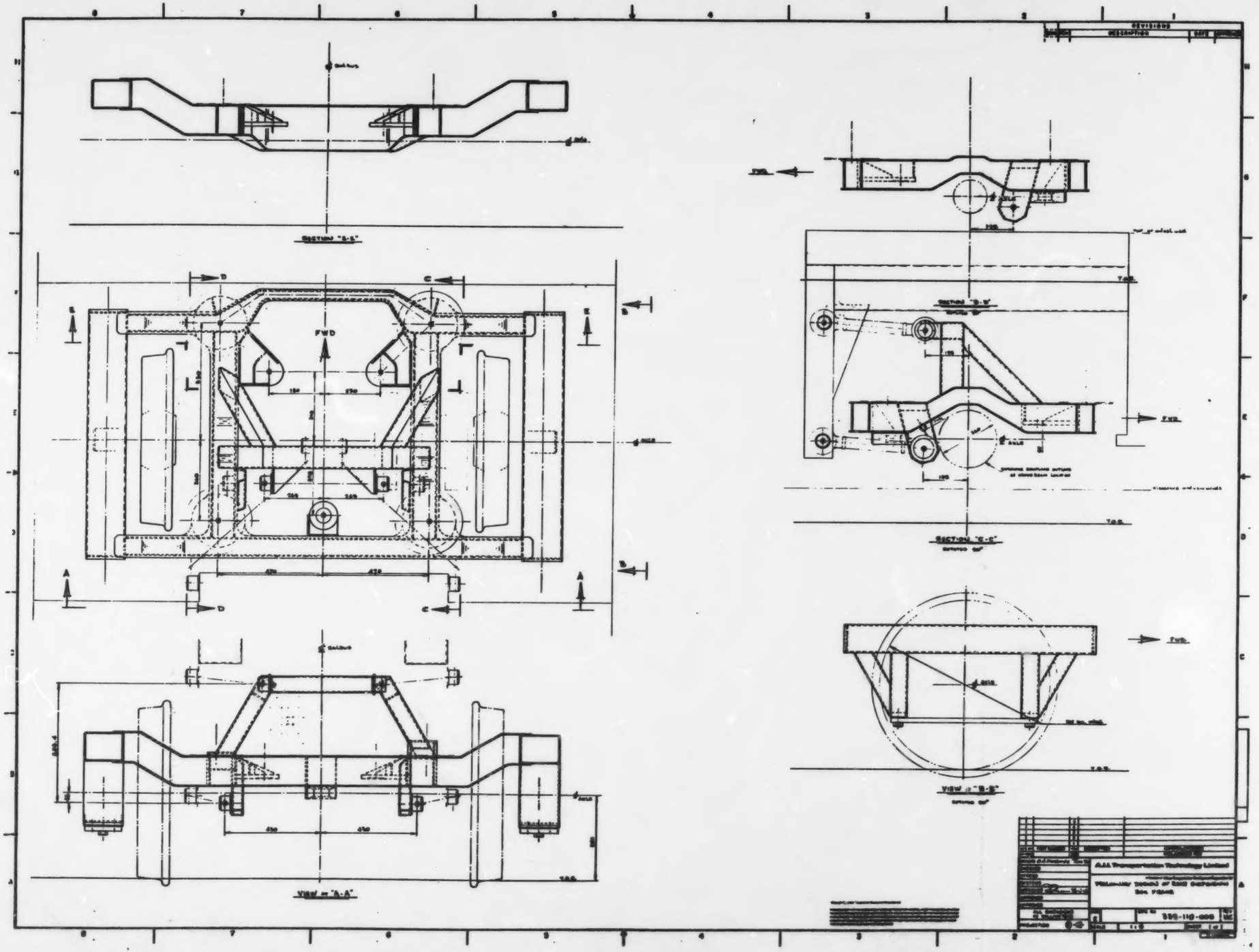
		DWG. NO. 539-110-004	REV.
		SCALE 1:20	SHEET 1 of 1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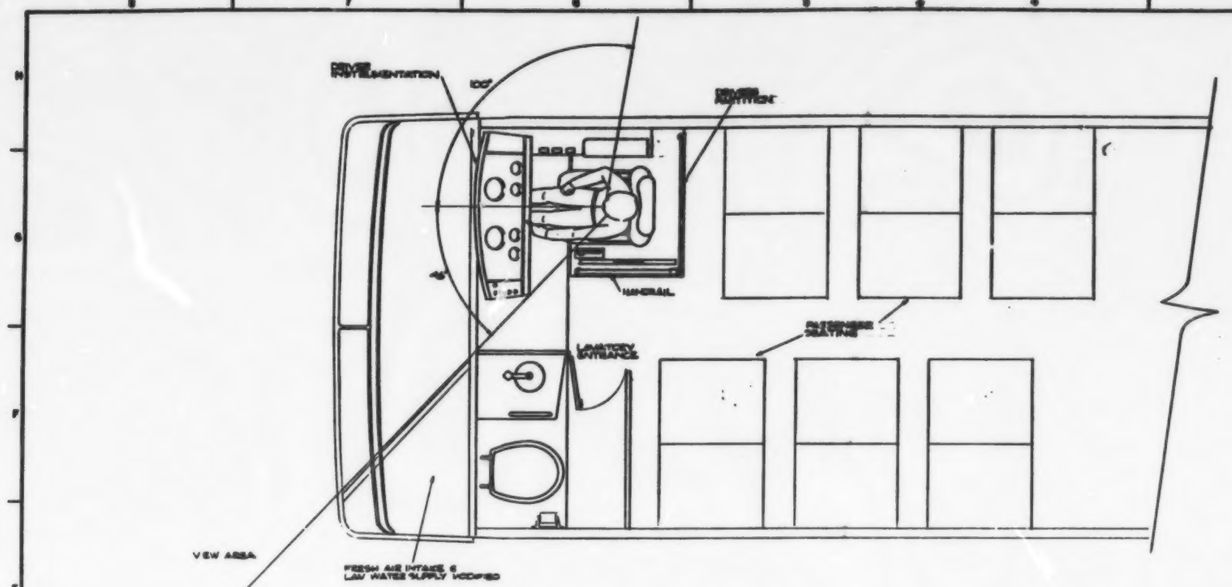
SECTION "C-C"
VIEW on "A-A"
VIEW on "D-D"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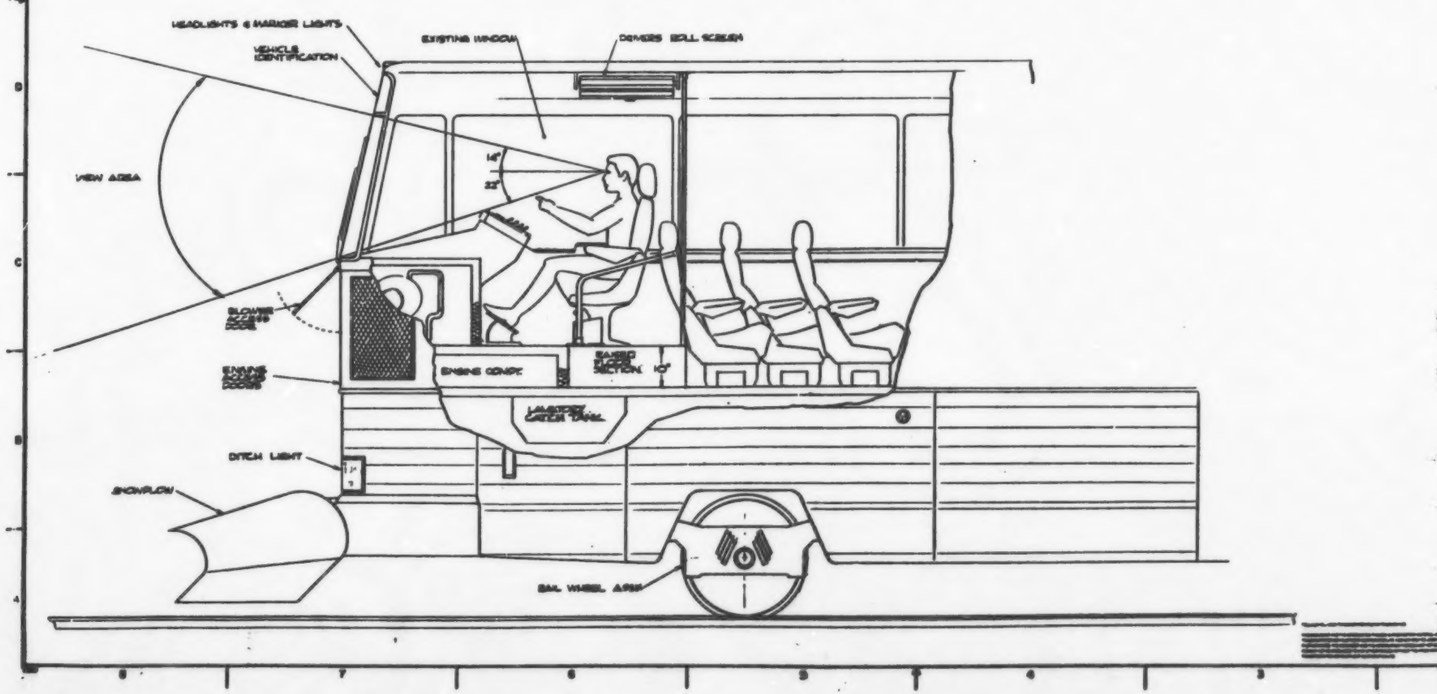
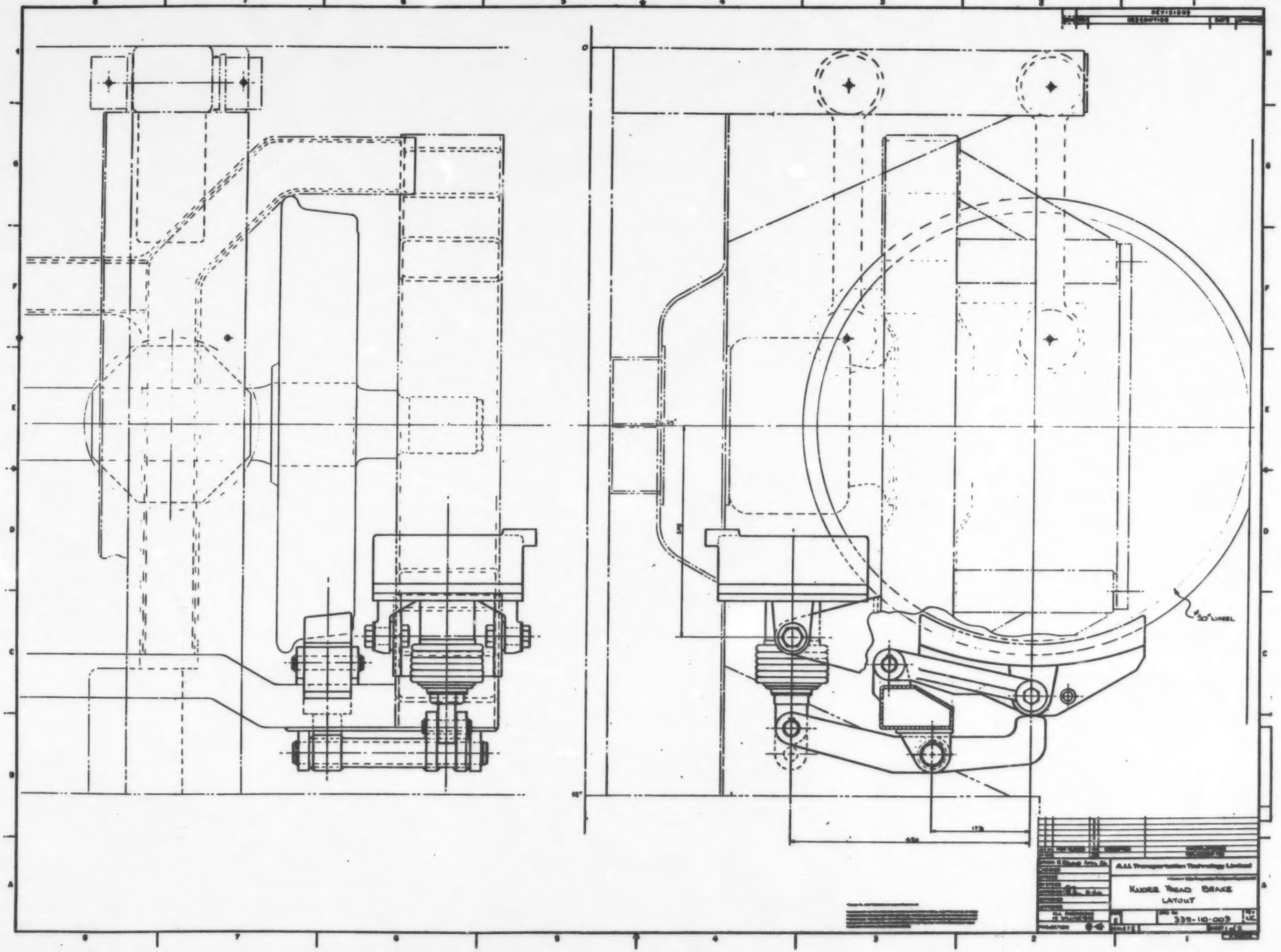
DOT
DRIVER POSITION
HANDRAIL
PASSENGER SEATING
LAVATORY ENTRANCE
VIEW AREA
FRESH AIR INTAKE & LAV WATER SUPPLY MODIFIED


HEADLIGHTS & MARKER LIGHTS
VEHICLE IDENTIFICATION
EXISTING WINDOW
DRIVERS ROLL SCREEN
VIEW AREA
BLOWER ACCESS DOOR
ENGINE ACCESS DOOR
ENGINE COMPT.
RADIO EQUIP. SECTION
LAVATORY WATER TANK
DITCH LIGHT
SNOWPLOW
TAIL WHEEL ASSY.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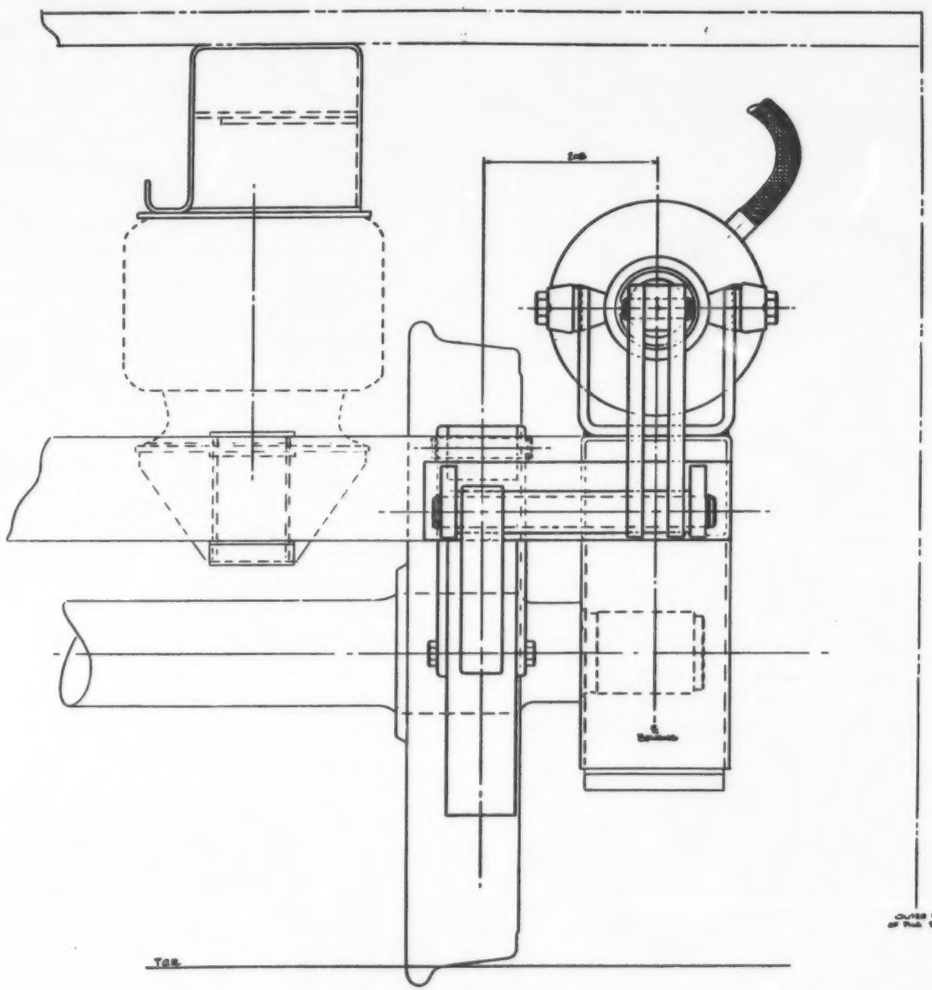
KNORR TREAD BRAKE
LAYOUT
339-110-003



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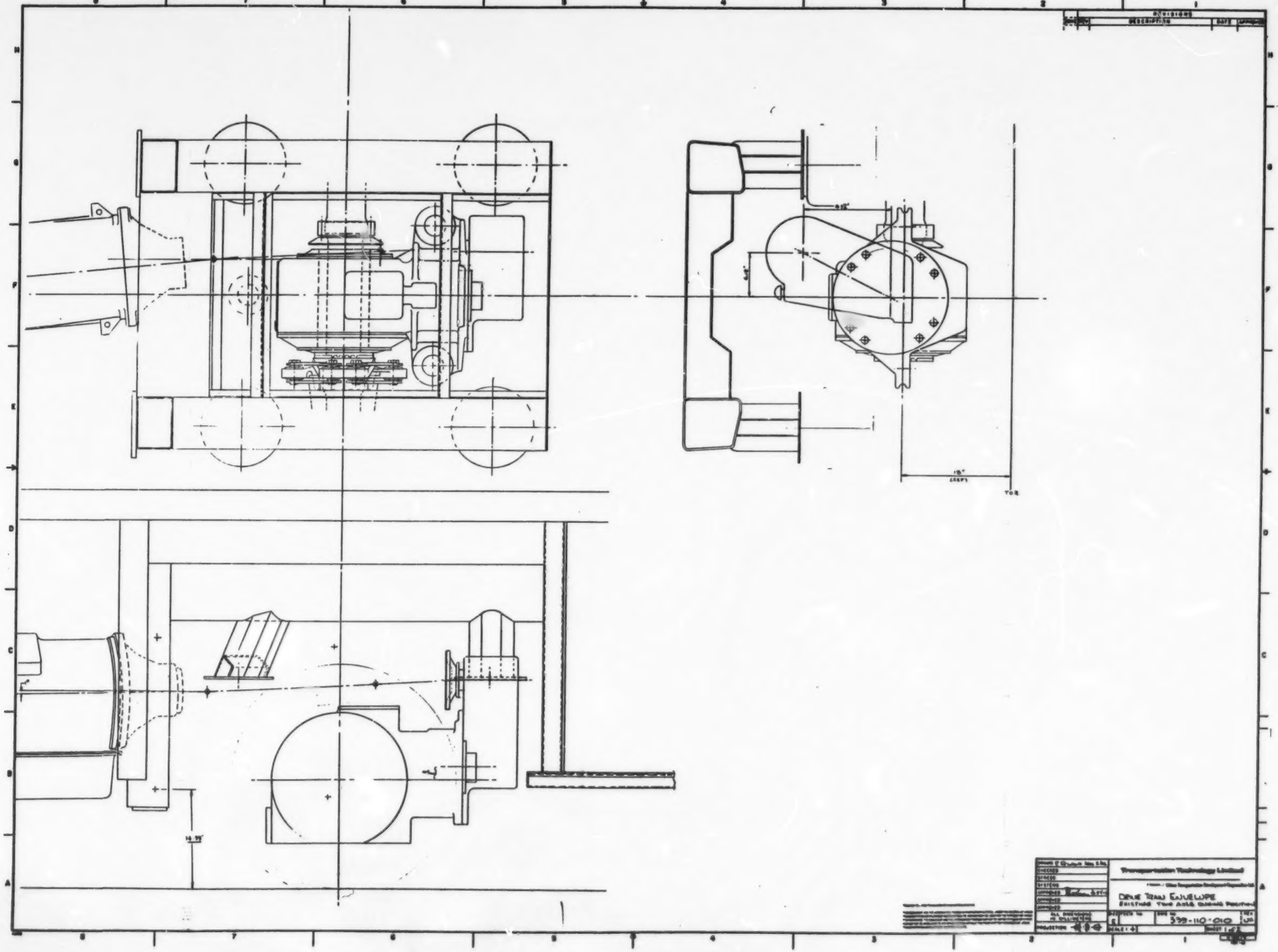
	LAYOUT
	SIZE No. 339-110-009
	SHEET 1 OF 1


Transportation Technology Limited
DRIVE TRAIN ENVELOPE
EXISTING TWO AXLE CHASSIS POSITION
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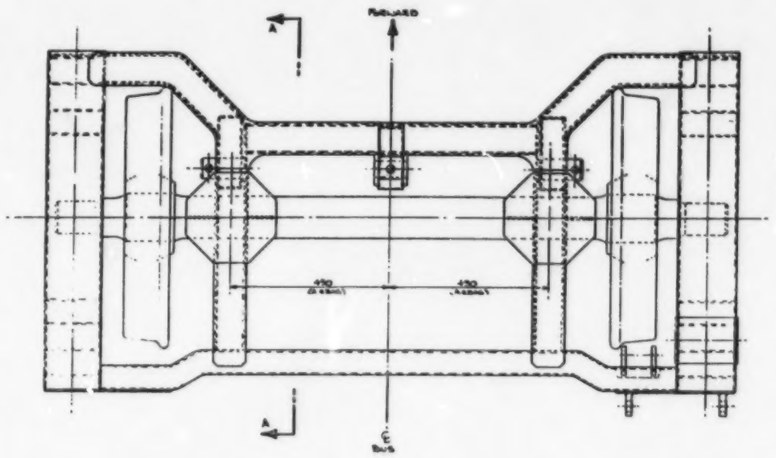
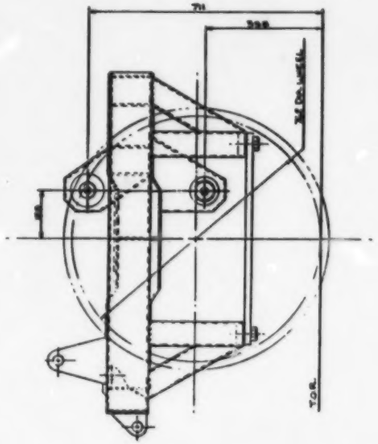
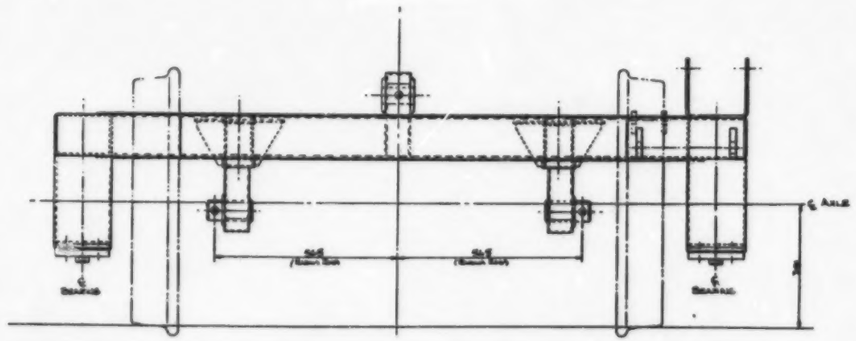
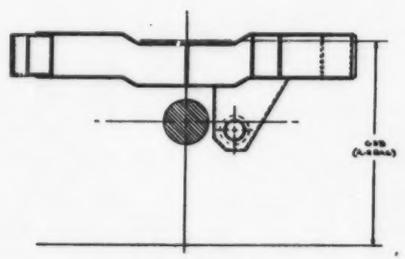






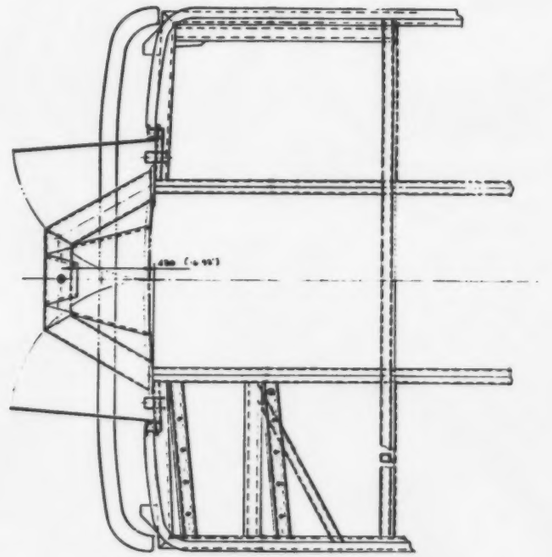


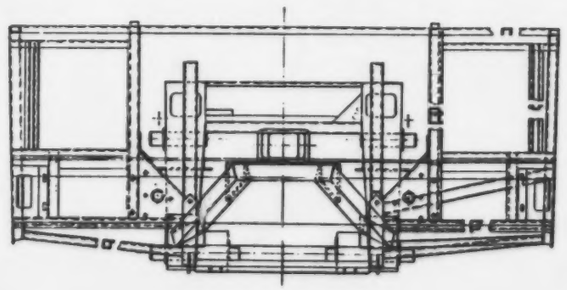
SEC. 'A-A' ROTATED 90°

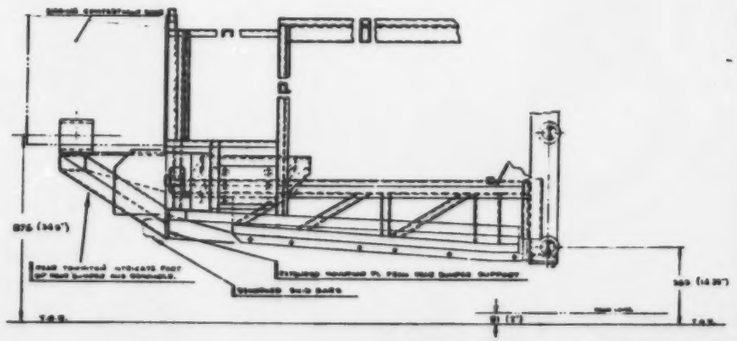
A.S.S. Transportation Technology Limited

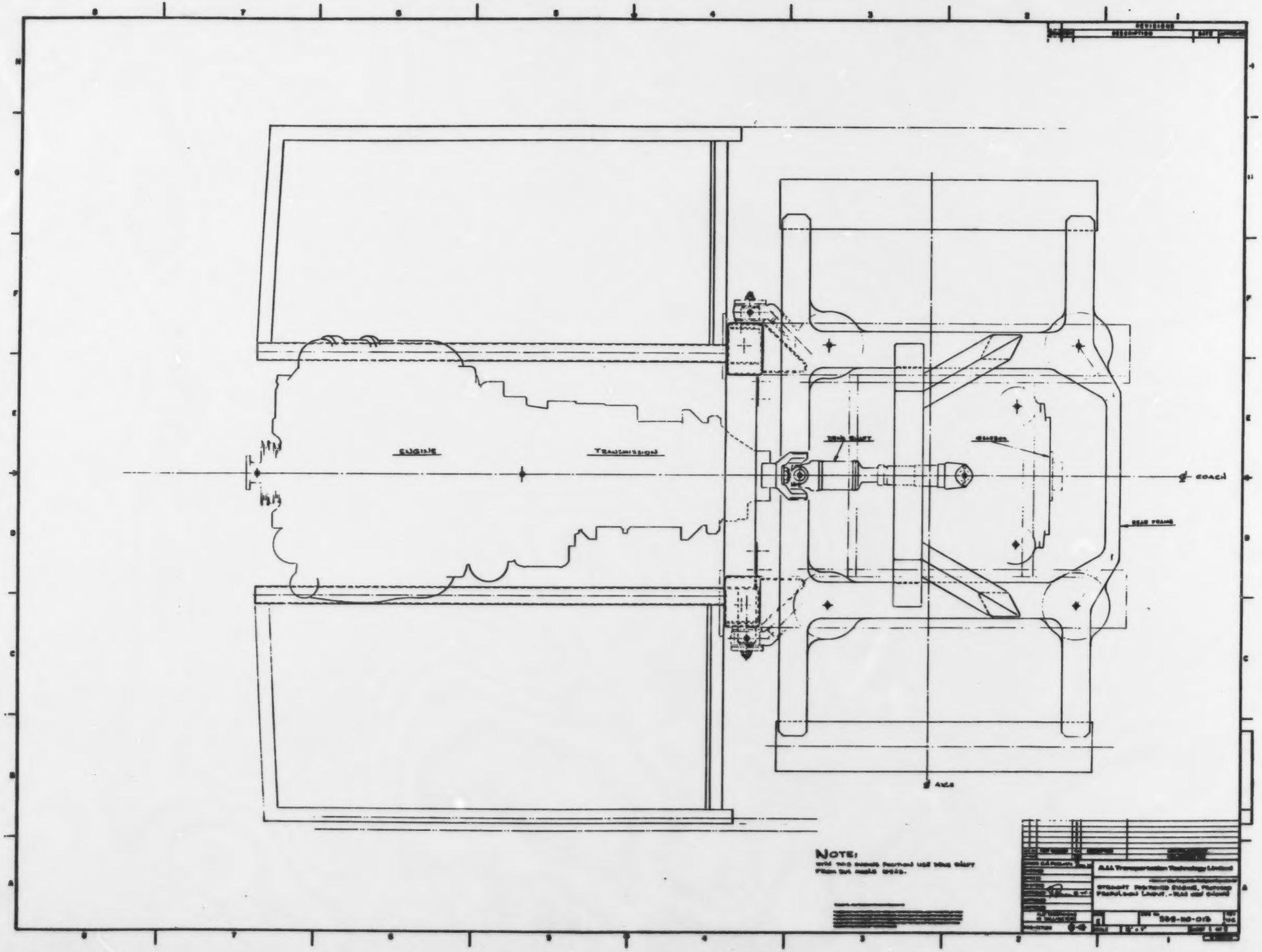
Preliminary Design of Four Continental Box Frame

339-110-011

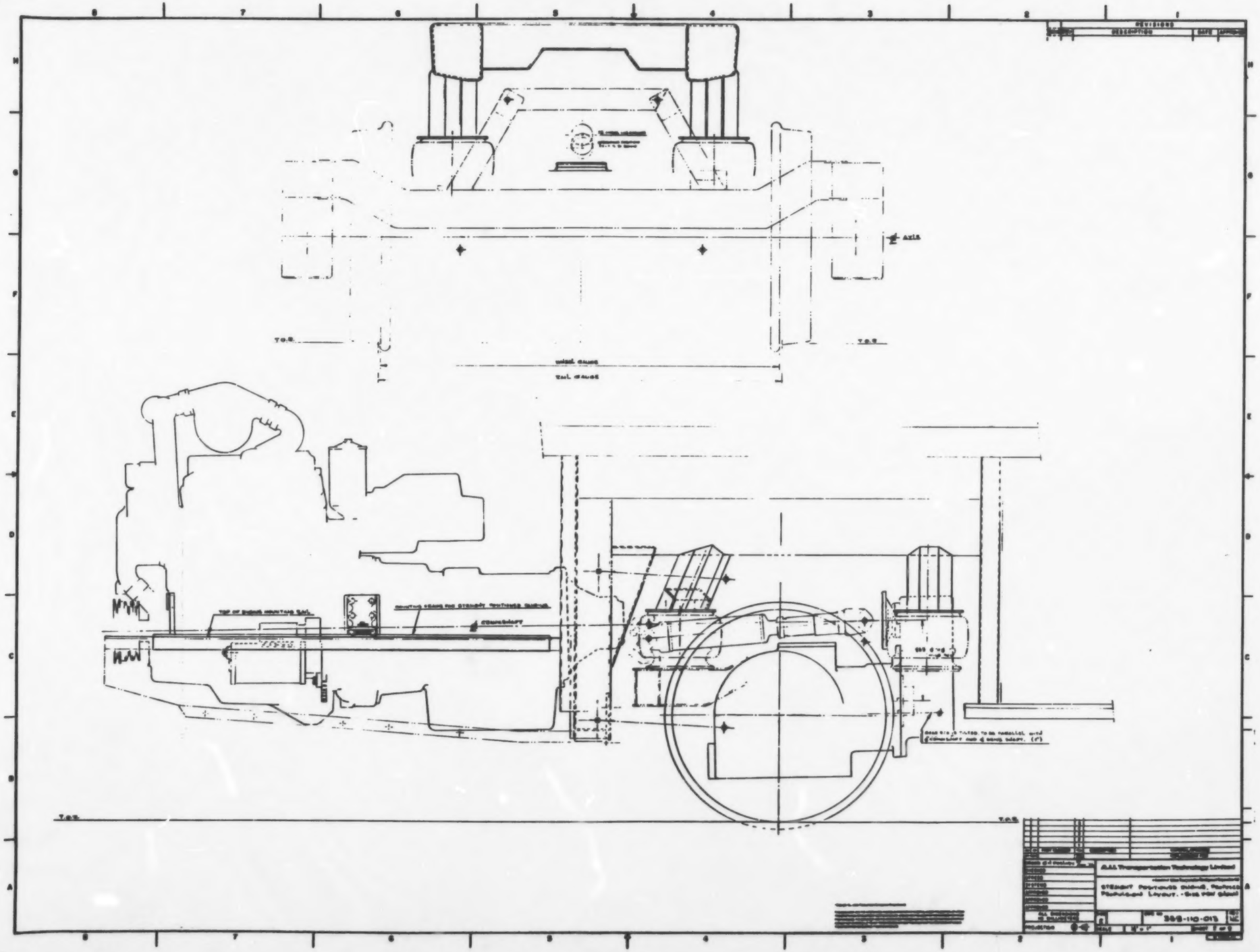




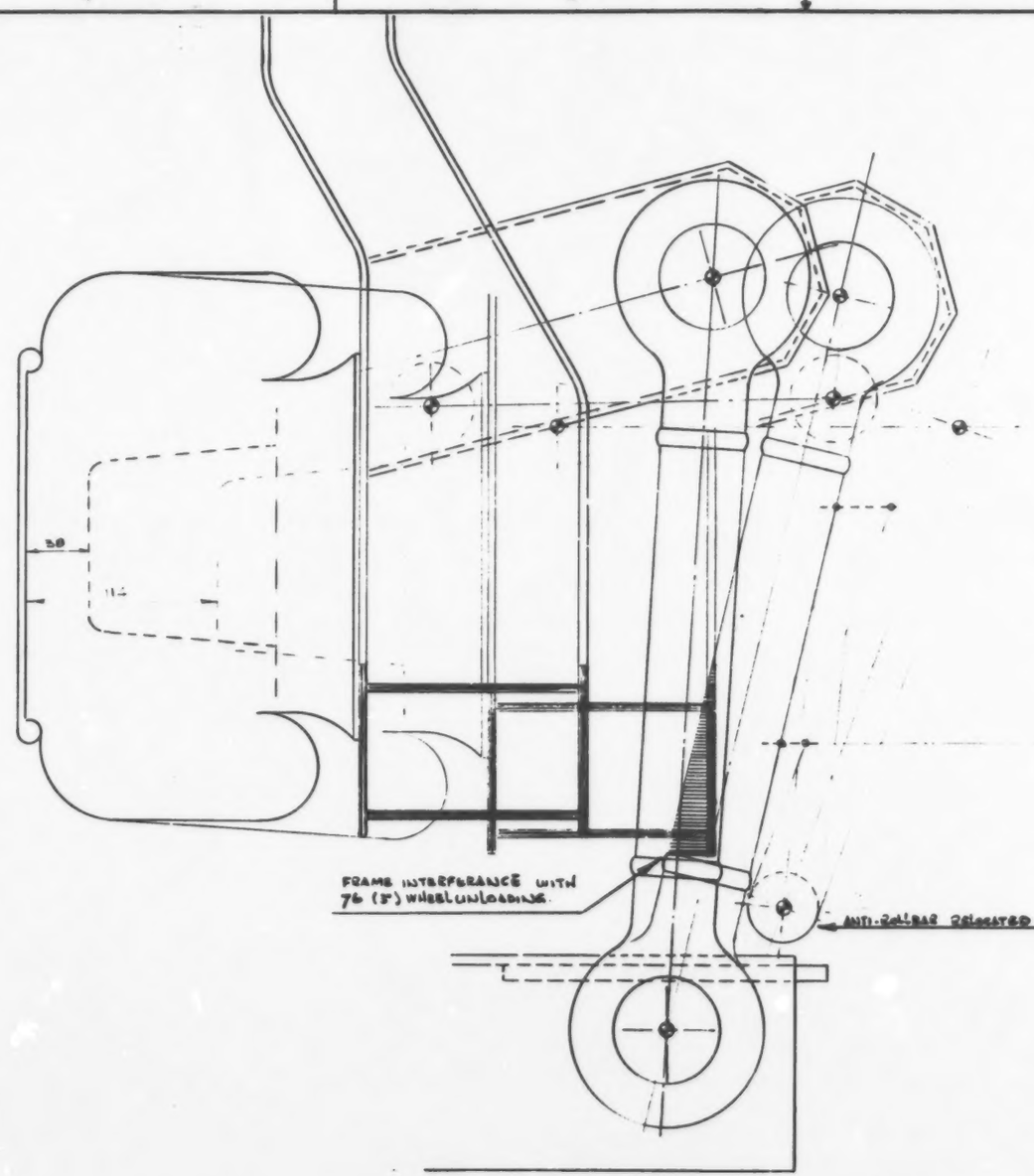


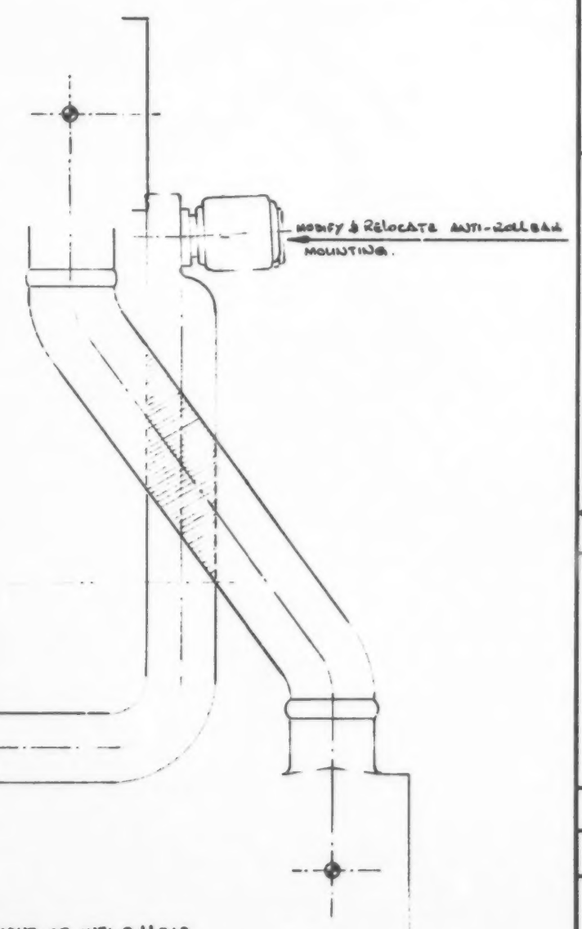


NOTE:
WHEN THIS DRAWING REFERRED TO DRIVE SHAFT FROM THE REAR AXLE.


AXIS
T.O.R.
T.O.R.
T.O.R.
T.O.R.
COUNTERSHAFT
A.A.L. Transportation Technology Limited
STRAIGHT POINTWORK ENGINE, PROTOTYPE
PROPULSION LAYOUT - SIDE VIEW (SHEET 1)
308-110-013

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED





LAYOUT OF ANTI-ROLLBAR
RED - IS SHOWN 76 (3") DOWN - WHEEL UNLOADING.

DRAWN	
CHECKED	
STRESS	
SYSTEMS	
APPROVED	
APPROVED	
ALL DIMENSIONS IN MILLIMETERS	
PROJECTION	

PROPOSED ANTI-ROLLBAR LOCATION AND MODIFICATION

SIZE	FSCM No	DWG No	REV
C		339-110-014	NC

SCALE 1:2 SHEET 2 of 3

A 9103/C

REVISIONS			
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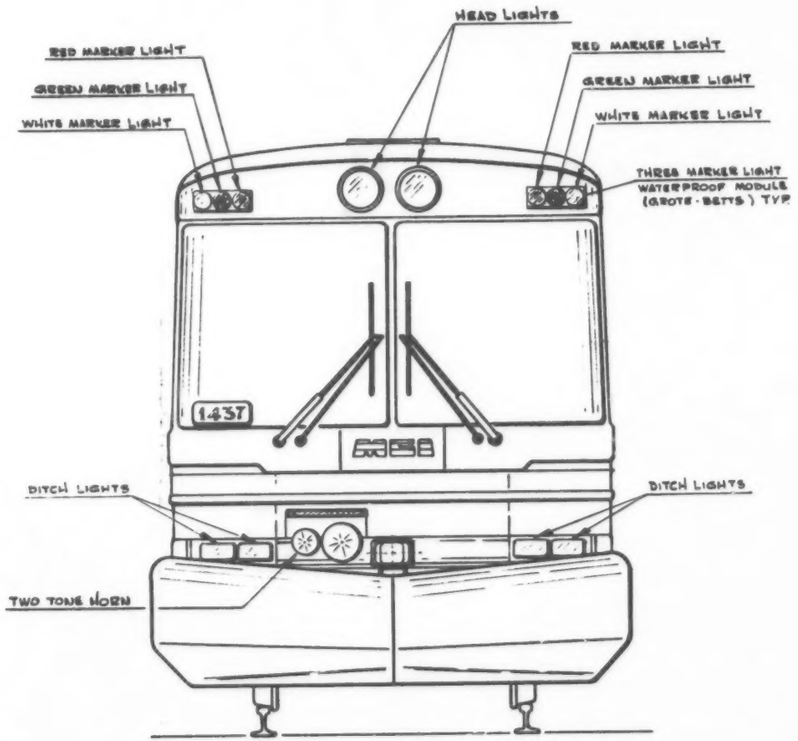
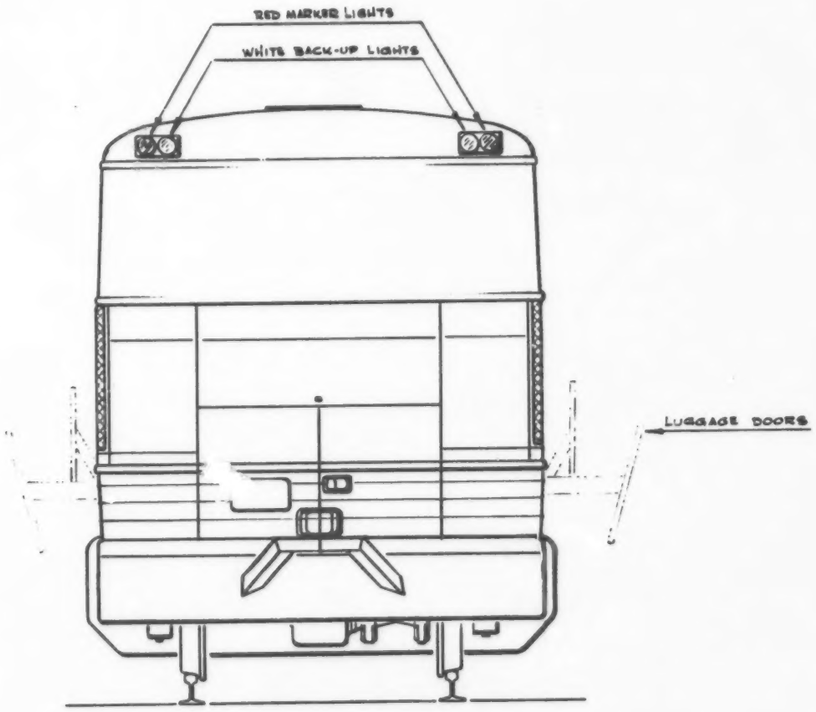


FRONT VIEW RAILBUS



REAR VIEW RAILBUS

DRAWN G.J. Pogliy'k		Transportation Technology Limited	
CHECKED			
STRESS			
SYSTEMS		EXTERIOR LIGHT & HORN ARRANGEMENT ON RAILBUS	
APPROVED			
APPROVED			
ALL DIMENSIONS IN MILLIMETERS		SIZE C	FSCM No
PROJECTION		DWG No 339-110-016	REV NC
		SCALE NTS	SHEET 1 of 1

R 9108/C

REVISIONS			
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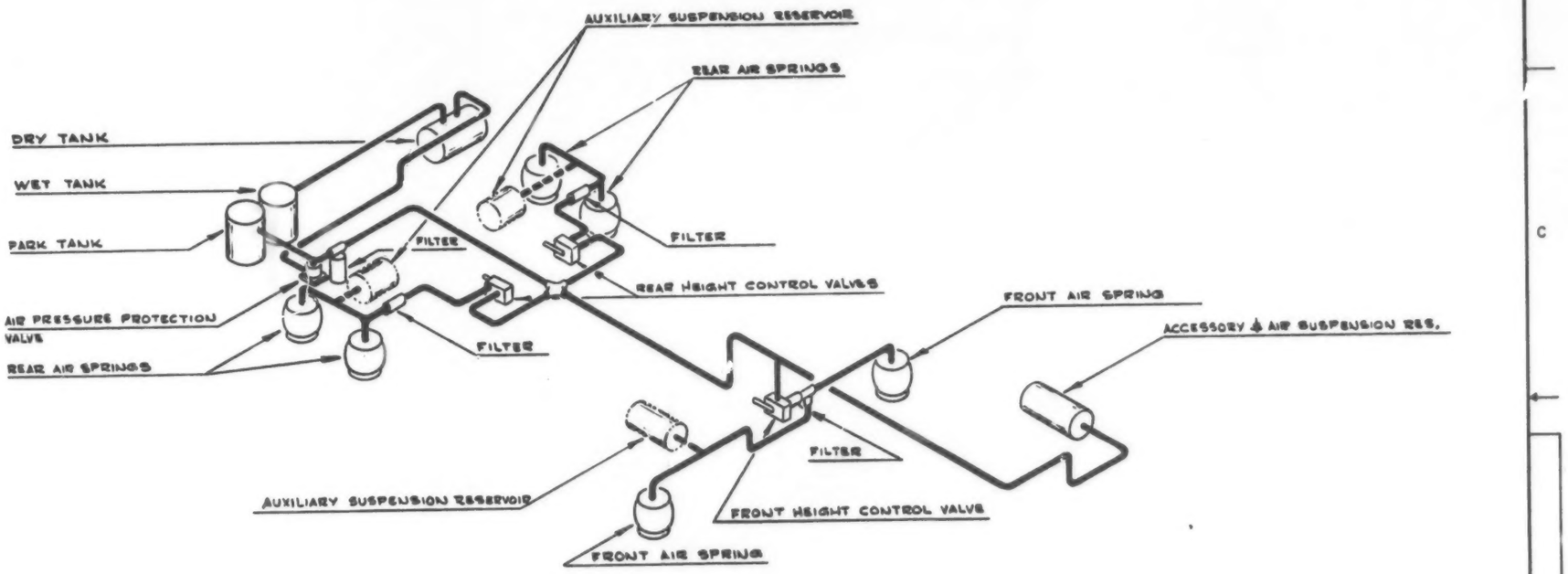


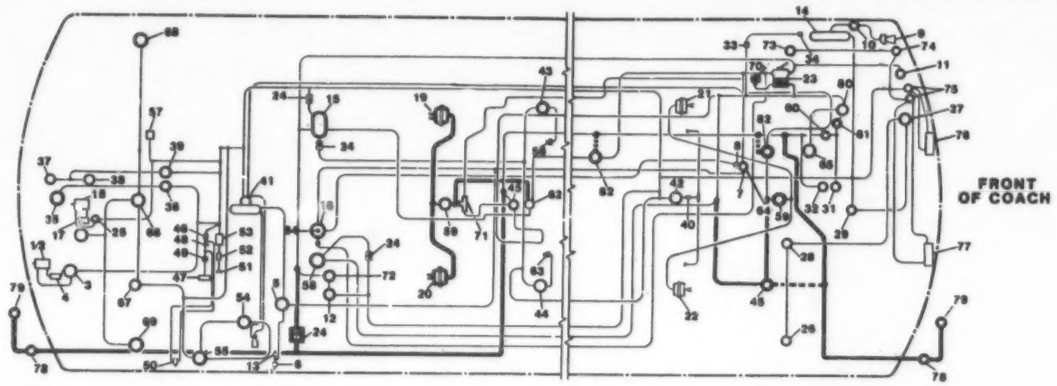
DRAWN G.W. POS-WYK	Transportation Technology Limited		
CHECKED			
STRESS			
SYSTEMS			
APPROVED	PROPOSED AUXILIARY SUSPENSION RESERVOIR LOCATIONS.		
APPROVED			
ALL DIMENSIONS IN MILLIMETERS	SIZE C / FSCM No	DWG No 339-110-017	REV NC
PROJECTION	SCALE NTS	SHEET 1 OF 1	

A 9105/C

COPYRIGHT ... THIS DRAWING AND THE INFORMATION THEREIN IS PROPRIETARY MATERIAL ...

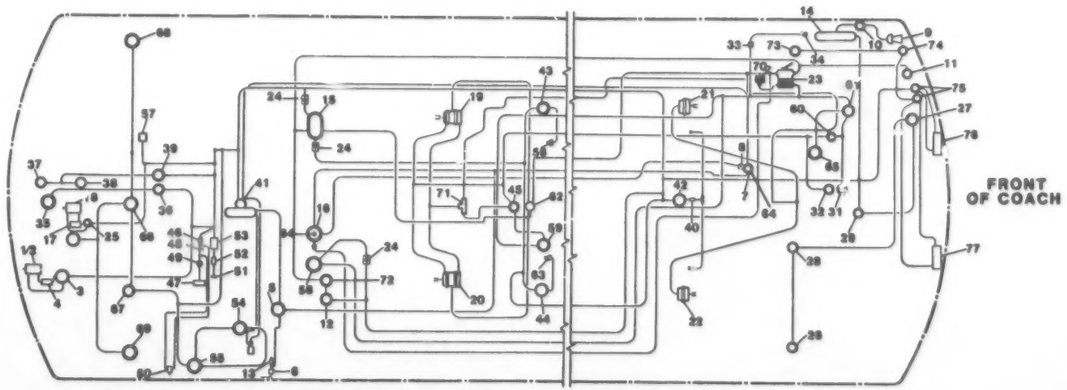
DWG No	SH	REV

ZONE	REV	REVISIONS DESCRIPTION	DATE	APPROVED
	A	RELOCATED #59 AT REAR WHL HSG. ADDED #82 ADDED #82, #59 & #45 AT FRONT WHL HSG.	5 JUNE 1986	



Proposed Air Line Diagram for the Railbus

1. Air Conditioning Compressor	Engine Comp.	28. Door Quick Release Valve	Spare Tire Comp.	53. Lavatory Door Pressure Regulator*	Under Lav. Sink
2. Air Conditioning Air Cylinder	Engine Comp.	29. Door Solenoid Valve	Spare Tire Comp.	54. Lavatory Dump Cylinder*	Engine Comp.
3. Air Conditioning Belt Tension Cylinder Control Valve	Engine Comp.	31. Emergency Brake Fast Idle Safety Switch	Spare Tire Comp.	55. Lavatory Manual Valve*	Engine Comp.
4. Air Conditioning Belt Tension Pressure Regulator	Engine Comp.	32. Emergency Brake Stop Light Switch	Spare Tire Comp.	56. Left Rear Suspension Air Filter	Rear Whl. Hsg.
5. Air Discharge Muffler	Engine Comp.	33. Emergency Fill Check Valve	Tool Comp.	57. Low Air Switch and Alternator Control	Engine Comp.
6. Air Discharge Muffler Drain Valve	Engine Comp.	34. Emergency Fill Schrader Valve	Tool Comp.	58. Park Air Tank	Engine Comp.
7. Air Dryer	Frt. Whl. Hsg.	35. Engine Shutdown Cylinder	Engine Comp.	59. Park Brake Pressure Regulator	Rear Whl. Hsg.
8. Air Dryer Check Valve	Frt. Whl. Hsg.	36. Engine Shutdown Solenoid Valve	Engine Comp.	60. Park Brake Quick Release Valve	Spare Tire Comp.
9. Air Horn*	Tool Comp.	37. Fast Idle Cylinder	Engine Comp.	61. Push-Pull Control Valve	Interior, Front
10. Air Horn Foot Valve	Driver's Footrest	38. Fast Idle Limit Cylinder	Engine Comp.	62. R-12 Relay Valve	Rear Whl. Hsg.
11. Air Pressure Gauge	Dash	39. Fast Idle Solenoid Valve	Engine Comp.	63. Right Rear Suspension Air Filter	Rear Whl. Hsg.
12. Air Pressure Protection Valve	Engine Comp.	40. Front Suspension Air Filter	Frt. Whl. Hsg.	64. Safety Valve	Engine Comp.
13. Air System Fill Check Valve	Engine Comp.	41. Governor	Engine Comp.	65. Service Brake Stoplight Switch	Spare Tire Comp.
14. Air Tank, Air Ride and Accessory	Tool Comp.	42. Height Control Valve, Front	Frt. Whl. Hsg.	66. Shutterstat	Engine Comp.
15. Air Tank, Dry	Engine Comp.	43. Height Control Valve, Rear Left	Rear Whl. Hsg.	67. Shutterstat Air Filter	Engine Comp.
16. Air Tank, Wet	Engine Comp.	44. Height Control Valve, Rear Right	Rear Whl. Hsg.	68. Shutter Cylinder Left*	Engine Comp.
17. Blower Belt Pressure Regulator	Engine Comp.	45. Inversion Valve	Rear Whl. Hsg.	69. Shutter Cylinder Right*	Engine Comp.
18. Blower Gearbox Belt Tension Cylinder	Engine Comp.	46. Lavatory Air Flush Pressure Regulator*	Under Lav. Sink	70. Shuttle Valve	Spare Tire Comp.
19. Brake Chamber, Left Drive Wheel	Rear Whl. Hsg.	47. Lavatory Air Flush Pump*	Engine Comp.	71. Two-Way Check Valve	Rear Whl. Hsg.
20. Brake Chamber, Right Drive Wheel	Rear Whl. Hsg	48. Lavatory Air Flush Push Button Control Valve*	Lav. Comp.	72. Type "E" Filter	Engine Comp.
21. Brake Chamber, Left Front	Frt. Whl. Hsg.	49. Lavatory Air Flush Quick Release Valve*	Under Lav. Sink	73. Windshield Washer	Tool Comp.
22. Brake Chamber, Right Front	Frt. Whl. Hsg.	50. Lavatory Air Flush Valve (External)*	Engine Comp.	74. Windshield Washer Valve	Dash
23. Brake Valve	Spare Tire Comp.	51. Lavatory Door Cylinder*	Lav. Comp.	75. Windshield Wiper Controls	Dash
24. Check Valves (Large and Small)	Engine Comp.	52. Lavatory Door Cylinder Metering Valve*	Under Lav. Sink	76. Windshield Wiper Motor, Left	Exterior, Front
25. Cylinder Control Valve	Engine Comp.			77. Windshield Wiper Motor, Right	Exterior, Front
26. Door Air Cylinder	Interior, Front			78. Brake Pipe Shutoff Valve	Exterior, Front/Rear
27. Door Manual Valve	Dash			79. Gladhand Fitting	Exterior, Front/Rear
				80. Deadman Control Valve	Interior, Front
				81. Deadman Isolation Valve	Interior, Front
				82. Pilot Operated Check Valve	



Existing Air Line Diagram of the MCI #102A2 Coach

NOTES:

BRAKES - Air Applied Service on Four Wheels

- Air Applied Emergency and Park on Rear Axle Only
- Hand Operated Park Brake Override on Front Axle Only
- Emergency, Deadman and Brake Pipe
- #78 , #79 , #80 , #81 , & One of #24 Added
- #61 Replaced by #80
- Relocated #59 in Rear Whl. Hsg.
- Added #45, #59, & #82 to Front Whl. Hsg.
- Added #82 to Rear Whl. Hsg.

DRAWN H Postuyk May 86	Transportation Technology Limited	
DETAIL	Urban Transportation Development Corporation Ltd	
STRESS	PROPOSED MODIFICATION TO THE AIR LINE DIAGRAM. (COACH MODEL 102A2)	
SYSTEM		
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ATTACHMENT A-3

DESIGN SPECIFICATION

FOR THE CANADIAN

ADVANCED RAILBUS

DESIGN SPECIFICATION FOR THE CANADIAN ADVANCED RAILBUS

Report No.: 339-410-001

Issue No.: 1

Copy No.:

Originator

Project Engineer

Date: 17 NOV 1986

Project Manager

Date: 17 Nov 1986

SUMMARY

This document forms the Design Specification for the Prototype Canadian Advanced Railbus.

The Design Specification for the Canadian Advanced Railbus is defined for Canadian remote rail applications and is based on preliminary design studies and performance studies documented in TTL Report no. 339-511-001 "Operating and Service Requirements for Advanced Railbus" and TTL Report no. 339-512-001 "Technical and Regulatory Requirements for Railbus Acceptance on Canadian Railways" (Reference 1 and 2).

The prototype design is based on a Canadian made Motor Coach Industries (MCI) Model 102A2 intercity highway bus which is termed "The Baseline Vehicle".

Bus modifications necessary to meet the Design Specification for the Canadian Advanced Railbus are identified and discussed in the Advanced Railbus Phase I Interim Report No. 339-710-001.

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APPENDIX I Baseline Vehicle Features - MCI 10[illegible]2

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APPENDIX III Condensed FRA Track Safety Standards

APPENDIX IV Applied Loads and Conditions

1.0 INTRODUCTION

No Canadian railbus vehicle is now available that is acceptable for use in general passenger service. A used Western Flyer bus has been converted for operation on railway tracks by Winnipeg Coach Sales and Service (WCSS) Ltd. This is a 30 year old vehicle, however, solely intended to serve as a test vehicle for the resolution of institutional and regulatory issues, for evaluation of related engineering design concepts, and to assess the overall feasibility of railbus operations in northern remote communities.

There are a few vehicles that have been developed overseas and that are available for importing into Canada. Generally, these have not been designed for conditions found in Canadian remote service routes. Their suspension and component systems are not designed/optimized for Canadian track quality which is oriented to heavy freight operation. Winterization is not adequate for Canadian weather conditions. Parts, materials, mechanical and electrical systems are generally of foreign manufacture and the use of these vehicles would require separate and larger inventories to compensate for lengthened delivery times. Maintenance training and practices would also have to be adjusted to allow for non-standard equipment.

AII Transportation Technology Ltd. (TTL) a wholly owned subsidiary of the Urban Transportation Development Corporation Limited (UTDC Ltd.) received a contract to develop a Canadian Advanced Design Railbus for remote service for the Department of Supply and Service (DSS) and the Transportation Development Center (TDC).

The Canadian Advanced Design Railbus will be based upon a standard intercity highway bus modified to operate in Canadian remote service rail applications.

2.0 OBJECTIVE

2.1 OVERALL OBJECTIVE

To develop technology suitable for rail services to remote communities where conventional rail service is extremely costly and suitable alternative modes of transportation are not available.

2.2 PROJECT OBJECTIVES

To design, build and test a prototype Canadian railbus vehicle of advanced design, conduct tests to demonstrate its performance, and obtain certification that the vehicle is acceptable for passenger-carrying service on the CN Rail line between Thompson-Pikwitonei-Thicket Portage.

2.3 DESIGN OBJECTIVES

To meet the project objectives of 2.2 above, and the performance criteria of 4.0 below with a minimum of modifications to a production intercity highway bus.

3.0 DESIGN SPECIFICATIONS

3.1 GENERAL

In order to take full advantage of the Railbus technology cost benefits, a standard production intercity highway bus shall be used as a baseline vehicle. Only those changes absolutely necessary to meet the relevant performance, operational, regulatory and safety requirements shall be made. In that light, the Canadian Advanced Railbus shall be designed to meet all relevant Canadian Motor Vehicle Safety Standards (CMVSS) and Federal Motor Vehicle Safety Standards (FMVSS) (US) with the modifications necessary to meet the relevant performance and operational requirements set out by the Canadian Transport Commission (CTC) and the Unified Code of Operating Rules (UCOR). In those areas where the performance criteria conflicts with existing railway regulations, relief shall be requested from the governing body (CTC) and the railroads. These areas are discussed in TTL Report No. 339-512-001 "Regulatory Requirements".

The Railbus shall be capable of operation on Canadian remote service routes.

The Railbus vehicle shall be capable of operation by a single person.

The Canadian Advanced Railbus shall be based upon a Canadian made Motor Coach Industries (MCI) 102A2 intercity bus. A description of those features on the MCI 102A2 bus which shall be retained for the Railbus modification is provided in Appendix I. In addition, those factory options which shall also be provided for the Railbus are listed at the end of Appendix I.

All modified or additional equipment and systems are described in the subsequent sub-sections.

3.2 DIMENSIONAL DATA

The following dimensions reflect changes from the baseline vehicle. All other dimensional data, as well as the unmodified bus dimensions, are provided in Appendix I.

DIMENSIONS

Length	Metres	Note
Overall	13,753 mm	Includes pilots at front and rear
Height		
Front & Rear (at axle)	3,420 mm	
Maximum	3,445 mm	Over roof hatches
Wheelbase		
To Centres of Front & Rear Axles	7,874 mm	
Track Gauge		
Standard Gauge	1,435 mm	
Ground Clearance		
T.O.R. to Body at Centre	355 mm	
T.O.R. to Bottom of Pilot	75 to 150 mm	

Entrance Step Height

T.O.R. to Retractable Step	240 mm
T.O.R. to 1st Step	444 mm

Overhang

Front (includes pilot)	2,565 mm
Rear (includes pilot)	3,307 mm

Floor Height From T.O.R.

Front (at axle)	1,320 mm
Rear (at axle)	1,396 mm

3.3 DETAILED WEIGHT ESTIMATES

The detailed weight estimates are shown in Appendix IV.

Empty Railbus weight estimate	14,418 kg
Load Capacity	4,204 kg
Gross Railbus weight estimate	18,622 kg

3.4 OPERATING REQUIREMENTS

3.4.1 Environmental Conditions

The vehicle shall be capable of operating reliably and safely when subjected to the conditions listed below:

Temperature:	-45°C to +38°C
Humidity:	10% to 100%
Wind:	Normal: 14 m/s (50 kph)
	Peak Gust: 30 m/s

Rain: 2 cm/hour; 3 cm/day, concurrent temperature range 1.5°C to 29°C, concurrent wind speed 11 m/s

Snow: 2.5 cm/hour; 13 cm/day, concurrent temperature range -9°C to +4.5°C, concurrent wind speed 13 m/s

Ice Accretion: 0.38 cm on vertical surface,
0.50 cm on horizontal surface

3.4.2 Track Conditions

The vehicle shall meet all of the following track related conditions.

Track: Standard gauge 4 feet 8½ inches
FRA Class 1 to Class 4 track (subject to the relevant speed restrictions for passenger traffic (See Appendix III).

Curves: The Railbus shall be able to negotiate a 23 degree (76.5 m radius) horizontal curve and a 152 m radius vertical curve.

Clearance Envelope: The vehicle shall meet the AAR Plate B unrestricted clearance envelope (See Appendix II).

Axle Loads: The axle loads shall meet AAR recommendations for unrestricted operation.

Crossings: The vehicle shall be able to safely negotiate road crossings.

Coupler/ Towbar Height: The railbus will be equipped with a removable towbar having a coupler centre line of 34.5 inches ATR and be able to be safely coupled to standard rail equipment.

3.4.3 Vehicle Capacity

The Railbus shall be designed to operate as a single vehicle unit having a seating capacity of 40 but shall be able to be modified to operate as a semi-permanent married pair of vehicles having a combined seating capacity of up to 80.

3.4.4 Baggage Capacity

Provision shall be made for the future use of a light baggage trailer capable of handling unusual and oversized baggage such as canoes, snowmobiles, food supplies, oil drums, etc.

Baggage space provided on the Railbus shall include overhead baggage racks as well as underfloor or equivalent storage compartments. Total capacity of the underfloor storage compartments shall not be less than 10.0 m^3.

3.4.5 Range and Speed

The Railbus shall be capable of continuous operation on tangent level track at 100 kph.

The vehicle shall have a minimum operating range of 1000 km before refueling or servicing is required. In addition, sufficient fuel capacity shall be available to operate emergency heating equipment (See Section 3.5.5).

3.4.6 Bi-Directional Operation

The Railbus vehicle shall be capable of independent bi-directional operation. The Prototype Railbus shall be provided with a driver's cab at the rear of the bus in order to allow complete bi-directional operation. Duplicate controls and switches shall be provided and a means to "lock-out" the unoccupied driver's cab controls shall be provided.

3.5 REGULATORY REQUIREMENTS

The Railbus vehicle shall be provided with existing highway safety equipment, structural requirements, lighting and signalling provisions except as outlined in the following subsections. All road related equipment which is not suitable for railroad application shall be removed.

3.5.1 Snow Plow/Pilot and Towbar Provisions

A suitable pilot shall be provided on the leading end(s) of the Railbus vehicle. The pilot shall be easily removable from the bus end frame structure. The structure of the pilot shall be capable of allowing jacking or lifting of the vehicle at fixtures provided for such purpose on the pilot. The structure of the pilot shall also allow the vehicle to be towed by existing railroad equipment. The pilot shall be of fabricated design and material shall be CSA G40.21 grade 44W low carbon steel. Welding shall be per CSA W59 standard practice.

The pilot shall be primed with red oxide primer and painted with an enamel top coat.

Provision shall be made for attachment of a removable towbar at both ends of the railbus. The towbar shall be easily removable and shall be stored in a readily accessible location on the Railbus. The towbar shall be capable of safely mating to existing railroad equipment.

Both the pilot and towbar shall be capable of withstanding a buff and draft jerk load equivalent to ±2 g acceleration of a loaded Railbus. Provision shall be made in the towbar for cushioning of the buff/draft loads. The towbar attachment points on the Railbus shall also be suitable for semi-permanent drawbar attachment of a light weight baggage trailer.

3.5.2 Lights, Bell and Horn

Headlights: No less than two headlights shall be provided on the leading end(s) of the Railbus. Such lights shall be located at the top center line of the Railbus front face and shall be capable of illuminating a person in dark clothing at a range of 183 m (600 ft). The headlight beam shall be directed at the center line of the track at a distance of 183 m (600 ft). The lights shall not protrude above the bus roof line and any protrusion beyond the front face of the bus shall be effectively sealed against the environment.

Ditchlights: Ditchlights shall be provided by the existing bus headlights.

Classification & Marker Lights: All required classification and marker lights shall be provided including while and green classification lights at the front and red marker lights to the rear. Each marker and classification light shall be independantly switched and indicator lamps shall be provided to verify correct illumination. Such lights shall be located at the top outside corners on the front face of the Railbus.

Train Number: A two digit illuminated train number shall be located on the front face of the Railbus such that it can be readily seen by a person standing at track level as the vehicle passes.

Emergency Lighting: Emergency lighting shall be provided in the event of main power failure. Such lights shall be automatically energized from the battery supply by a relay which is activated when main supply voltage is lost.

Bell: An electronic or electromechanical bell shall be provided on the Railbus. Tone and loudness of the bell shall be similar to the railway standard 30 lb bell. The bell shall be operated from a switch at the driver's console.

Horn: A two tone air horn capable of 96 dBA at 30 m shall be located at the front of the Railbus mounted on the pilot. Suitable air reservoir capacity shall be provided for normal horn operation, and safety features shall be provided which ensure that the service brake air system is not depleted by normal operation of the

horn. A horn control valve shall be operated from the driver's compartment. A baffle shall be provided over the top of and behind the horn in order to minimize noise levels in the Railbus.

3.5.3 Safety Equipment

A cabinet containing the following items shall be provided in a readily accessible location in the passenger compartment of the Railbus.

- a red flag on a staff;
- a white light;
- torpedoes; and
- fuses.

A suitable fire extinguisher shall be provided in the passenger compartment.

An emergency tool kit shall be provided in an accessible location in the passenger compartment consisting of the following items:

- one - 2.7 kg sledge hammer (6 lb);
- one - 2.0 kg axe (4½ lb); and
- a hand saw.

Other emergency equipment which shall be provided on the vehicle includes the following:

- a stretcher;
- a first aid kit;
- a shovel;
- a pike;

- a crow-bar; and
- a switch broom.

3.5.4 Communications

A suitable two-way FM radio capable of providing communication with the train dispatcher and other railway employees shall be provided.

3.5.5 Emergency Heating

Emergency heating equipment shall be provided independant of engine power. Such heating system shall be capable of maintaining a 10°C interior temperature for a 24 hour period while outside ambient temperature is -40°C and wind velocity is 50 kph.

3.6 DYNAMIC STABILITY/RIDE QUALITY AND CURVING PERFORMANCE

The Railbus shall demonstrate dynamically stable behaviour with an effective .2 conicity wheel profile at all speeds up to the FRA recommended speed limitations for passenger vehicles on the particular track classes and an overall maximum speed of 100 kph (See Appendix III).

For the purpose of this specification dynamic instability shall be defined as continuous severe flange to flange oscillation with no indication of improvement until vehicle speed is significantly reduced.

Vehicle ride quality objectives shall be 2.5 on the British Rail Ride Index scale when operating at 70 kph on the Thompson-Pikwitonei-Thicket-Portage line where speed limits allow (See Table 3.6 "British Rail Ride Index in Terms of Passenger Comfort").

Ride Index	Quality of Ride
1.0	Very good
1.5	Almost very good
2.0	Good
2.5	Almost good
3.0	Satisfactory
3.25	Satisfactory with limitations
3.5	Just satisfactory
4.0	Operable
4.5	Not operable
5.0	Dangerous

TABLE 3.6: BRITISH RAIL RAIL INDEX IN TERMS OF PASSENGER COMFORT

The Railbus shall be capable of negotiation of a 23 degree curve (251 m radius). Self-steering ability of the axles shall be optimized against dynamic stability.

3.7 STRUCTURAL CONSIDERATIONS

The Railbus shall be provided with single axle railroad suspension trucks at the existing front and rear road wheel locations.

Design loads and conditions for the truck frame and related components are summarized in Appendix IV. No structural reinforcement of the existing highway bus other than local

strengthening for front and rear towbar/pilot attachment, rear driver cab modifications and truck mount modifications shall be made.

3.7.1 Rear Truck Frame and Suspension

The rear truck frame shall be of fabricated design and material shall be CSA G40.21 grade 44 W low carbon steel or equivalent. Welding shall be per CSA W59 continuous full penetration welds. Inspection shall be die penetrant and visual inspection; no cracks, undercuts, craters or inclusions allowed and no visible porosity. Repair as required by excavation and weld repair. The frames shall be primed with red oxide primer and painted with one coat enamel.

Stress analysis shall be performed on the frame based on the loading conditions in Appendix IV. The analysis shall be finite element with supporting hand calculations.

The rear truck frame shall provide support for the drive train gearbox and dropbox and shall provide mounting locations for the necessary primary and secondary suspension elements. Mounting points for suitable traction/radius rods and anti-roll bar shall also be provided on the frame.

Rear truck secondary suspension shall remain the same as the baseline vehicle and shall include two pair of rolling lobe airbags on each side of the truck fore and aft of the axle centre line. Each side of the rear truck secondary suspension shall be independently leveled.

Primary suspension of the rear track shall be provided by a pair of rubber laminated chevron springs mounted directly over each bearing assembly. Mounting of the chevron pairs shall have sufficient adjustability to allow for creep, and a safety

tiebar shall be provided under the assembly to retain the wheelset during jacking of the vehicle or during the derailment.

3.7.2 Front Truck Frame and Suspension

The front truck frame shall be of fabricated design and material shall be CSA G 40.21 grade 44 W low carbon steel or equivalent. Welding shall be per CSA W59 continuous full penetration welds. Inspection shall be die penetrant and visual inspection; no cracks, undercuts, craters or inclusions allowed and no visible porosity. Repair as required by excavation and weld repair. The frames shall be primed with red oxide primer and painted with one coat enamel.

Stress analysis shall be performed on the frame based on the loading conditions in Appendix IV. The analysis shall be finite element with supporting hand calculations.

The front truck frame shall provide mounting locations for the necessary primary and secondary suspension elements. Mounting points for suitable traction/radius rods shall also be provided on the frame.

Front truck secondary suspension of the Railbus shall remain the same and shall be provided by two rolling lobe airbags with a simple leveling valve.

Primary suspension of the front truck shall be provided by a pair of rubber laminated chevron springs mounted directly over each bearing assembly. Mounting of the chevron pairs shall have sufficient adjustability to allow for creep, and a safety tiebar shall be provided under the assembly to retain the wheelset during jacking of the vehicle or during a derailment.

3.8 PROPULSION

A suitable interface drop-box and axle drive shall be provided to match the bus manufacturer supplied engine and transmission. Such drive train shall be capable of full speed operation in both directions of travel.

Sufficient power shall be available to overcome train resistance including up to 3 percent grades, air drag, rolling resistance, accessory loading and snow-plowing.

The average fuel consumption objective is 28.0 litres/100 km (10 mpg) and target fuel consumption is 23.0 litres/100 km (12.3 mpg).

A suitable rail sanding device shall be provided in front of the driven axle.

3.8.1 Rear Drive Train

A sketch of the drive train arrangement is shown below in Figure 3.8.

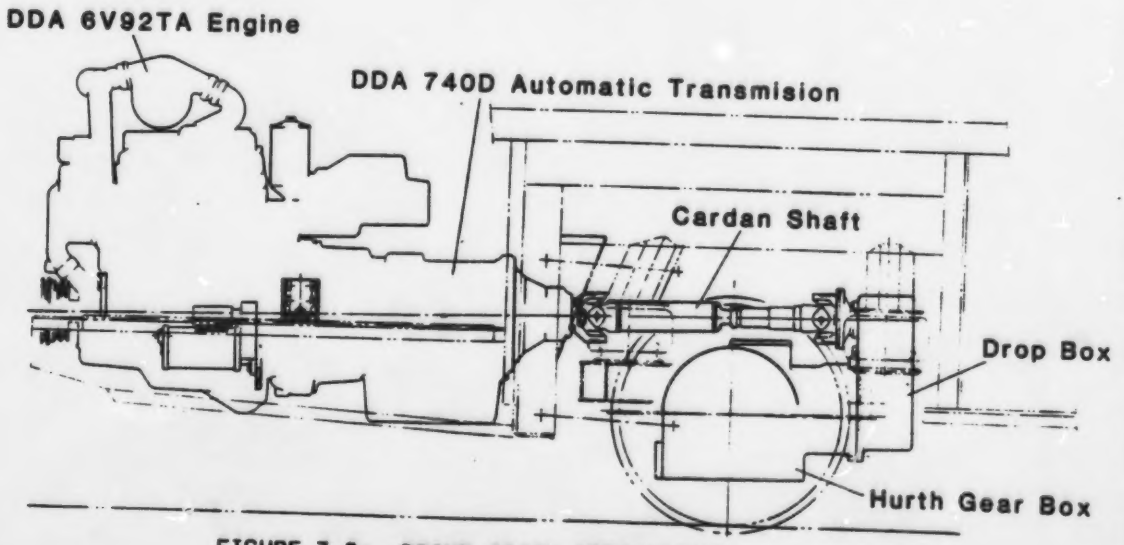


FIGURE 3.8: DRIVE TRAIN ARRANGEMENT

The power plant shall be a standard North American Diesel Engine with a matching automatic transmission. A standard universal joint cardan shaft shall drive a dropbox/reverser from the automatic transmission. The dropbox/reverser shall mount directly to a railway type fully bi-directional right angled drive gearbox which shall drive the axle via a flexible coupling.

The individual drive train components shall meet the following requirements.

Engine: Turbocharged diesel of North America manufacture.

Transmission: North America automatic automotive transmission with lock-up in top gears.

Cardan Shaft: Standard SAE flange mounted needle bearing universal joints with splined shaft.

Dropbox/ Reverser: A heavy duty dropbox with integral reverser shall be designed to meet the loading conditions outlined in Appendix IV and the space constraints of the Railbus. The reverser shall include equal full power performance in both the forward and reverse directions and shall have the capability to decouple the drive axle from the engine power. High quality gearing shall be utilized to minimize noise and vibration. The dropbox/reverser lubrication shall be self-contained and accessible oil fill and drain plugs shall be provided. A suitable inspection cover shall be provided.

GearBox/ Coupling: A right angle drive gearbox shall be provided which mates to the dropbox/reverser. The gearbox shall be mounted on resilient mounts to the rear truck frame. The gearbox shall provide sufficient clearance around the axle to allow for primary suspension motions. The gearbox lubrication shall be self-contained and accessible oil fill and drain plugs shall be provided. A suitable inspection cover shall be provided. A flexible drive coupling capable of operating under full power in both directions shall be provided.

3.8.2 Axle/Wheelset

Axles: The axles shall meet the following requirements.

Axle Material Specification

Special Alloy steel "42 Cr Mo 4" similar to DIN 17.200 (or SAE 4140 H).

- quenched and tempered to a tensile strength of 690 to 830 N/mm^2

- Notched bar impact value according to DIN 50115 at least DVM 41 J

- bending fatigue strength at least 275 N/mm^2 (unnotched specimen according to DIN 50113)

- Brinell hardness 204 - 249 HB30

Axle Manufacturing Specification

The axles may be formed either by rolling or by forging, or by a combination of both methods. If forging is used the reduction in cross-section at each heat must be properly controlled. The size of the finished forged or rolled section must contain sufficient machining allowance to ensure that surface defects do not show in the machined axle.

If the axles are produced by first rolling and then forging, the ingot before rolling must be at least four times larger than the final section after forging, and the rolled section before forging must be a least twice the cross-sectional area of the finished forging.

If the axles are only forged, the minimum starting section of the rough ingots must be three times the final section.

If the axles are only rolled, the minimum starting section of the rough ingots must be five times the final section.

The finished axles shall show no rough surface spots.

Machining of the wheel seats must be done with the cutting tool travelling from the axle end toward the centre.

All the radii of the axle must be cross-polished. For cross-polishing, the tool is covered with fine emery tape (grain 320), and approached to the slowly rotating axle (about 10 rpm) in such a way that the centre line of the rotating tool shaft (about 25000 rpm) is exactly perpendicular to the centre line of the axle. The result is that the pattern of the surface finish striations run in the axial direction.

Axle design loading shall be 24,000 lb (10,889 kg).

Wheels: The wheels shall meet the following requirements.

- 30 inch (762 mm) tape line diameter
- wheels shall be marked per AAR specification M-107 of latest revision
- hub and rim diameter shall be concentric within .76 mm total indicated reading of tread diameter.
- material shall be AAR specification M107 Class C wrought carbon steel with a minimum hardness of 321 Brinell and a maximum hardness of 363 Brinell.

Bearings: The bearings shall be double tapered roller type and shall comply with AAR Standards. Lubrication shall be provided by grease equivalent to Arapen RB 350. Suitable approved

seals shall be provided to exclude dirt from the bearing and to retain grease. B-10 service life shall be calculated based on the loading conditions in Appendix IV.

3.9 BRAKING PERFORMANCE

The brake system shall utilize the existing on board pneumatic system with a minimum of modification and shall provide the following performance requirements.

The brake system shall comply with all railroad governing regulations. The brakes shall be tread brake type for the prototype Railbus. Emphasis shall be placed on simplicity of equipment and rugged design. Equipment such as the actuator and shoe holders shall be rail type equipment. Provision shall be made for the incorporation of anti slide equipment in the future. A single actuator and shoe holder shall be provided at each wheel.

Deadman Control/Brake Pipe

A brake pipe with suitable glad-hand fittings shall be provided to allow recovery from either end of the vehicle by existing railroad equipment. A suitable deadman control shall be incorporated with the brake pipe.

Service Brake

Nominal deceleration shall be .89 m/s^2 (2.0 MPHPS) on tangent level track. Minimum brake rates shall be .80 m/s^2 (1.8 MPHPS). The service brakes shall be air applied and shall be capable of stopping the vehicle on a 3% downgrade from 100 kph operating speed.

The service brake equipment shall be compatible with available anti-slide equipment and both front and rear brake rates shall be independantly adjustable. The service brake air system shall be isolated from all other air system functions such that service brakes shall be operable in the event of a failure in the balance of the air system.

Emergency Brakes:

Emergency brake rates shall be air applied and shall be at least equal to full service brake rates. A deadman control and a brake pipe trainline shall be provided which is compatible with existing railroad equipment. Venting of the brake pipe shall cause full emergency brakes to be applied.

Park Brakes:

Air applied park brakes shall be provided which shall be capable of holding the vehicle on a 5% grade. A spring applied or a mechanical override park brake operated from a location near the front entry door shall be provided.

3.10 MISCELLANEOUS ITEMS

3.10.1 Passenger Door

A single passenger access door shall be provided at the front of each single unit Railbus.

3.10.2 Handicapped/Elderly Access

Provision for handicapped access in terms of a hydraulic wheelchair lift shall be made as an option on a production Railbus. Provision for handicapped access on the prototype

Railbus shall be limited to use of larger seat spacing and seat width. In addition, an area shall be set aside as provision for a potential retrofit of a suitable wheelchair handling unit.

3.10.3 Food Services

Provision shall be made for an optional galley capable of providing both hot and cold drinks and snacks.

3.11 MAINTAINABILITY AND RELIABILITY

The Railbus shall be based on existing reliable intercity bus technology and only a minimum of modifications shall be made to meet railroad operating requirements in order to maintain the highest possible levels of reliability.

Those modifications which are made will be done in a manner so as to maximize reliability while still meeting other design criteria of cost and maintainability. The vehicle shall be such that, an automotive bus mechanic shall be able to perform normal maintenance on the vehicle with a minimum of additional training.

4.0 REFERENCES

1. TTL Report no. 339-511-001 "Operating and Service Requirements for Advanced Railbus".

2. TTL Report no. 339-512-001 "Technical and Regulatory Requirements for Railbus Acceptance on Canadian Railways".

APPENDIX I

BASELINE VEHICLE FEATURES

MCI 102A2

BASELINE VEHICLE FEATURES

MCI 102A2 BUS SPECIFICATIONS (In Road Trim)

DIMENSIONS

Length	Feet/Inches	Metres	Note
Over Body	39' 10.25"	12,147 mm	Includes front energy absorbing bumper
Over Bumpers	40' 2.25"	12,249 mm	
Add Rear Bumper Cushion	40' 4.25"	12,299 mm	
Inside (Back Panel to Dash)	35' 10.5"	10,935 mm	
Width			
Over Body	102"	2,590 mm	Excludes side mirrors, turn lights, fenders
Over Front	98.2"	2,494 mm	
Over Rear	101.4"	2,576 mm	
Height			
Front & Rear (at axle)	132.67"	3,370 mm	
Maximum	133.67"	3,395 mm	Over roof hatches

Wheelbase

To Centres of Front & Rear Axles	310"	7,874 mm	

Track

Front	85.7"	2,177 mm	
Rear	76.9"	1,953 mm	To centre of duals

Ground Clearance

To Body at Centre	12.0"	305 mm	
Approach Angle	11 Degrees		
Departure Angle	10 Degrees		

Entrance Step Height

Ground to 1st Step	15.5"	394 mm
1st to 2nd Step	9.5"	241 mm
2nd to 3rd Step	9.5"	241 mm
3rd to Floor	9.5"	241 mm
Width of Step	26.0"	660 mm
Ground to Retractible Step	8.0"	203 mm

Overhang

Front (includes front bumper)	73.75"	1,873 mm
Rear (over optional help bumper)	103.63"	2,632 mm

Floor Height From Ground Level

Front (at axle)	50.0"	1,270 mm
Rear (at axle)	53.0"	1,346 mm

Headroom

Aisle to Ceiling

Front-at Rear of 1st Seat	78.92"	2,005 mm
Rear	75.92"	1,928 mm

Floor Line to Parcel Rack

Front	68.0"	1,730 mm
Rear	65.0"	1,651 mm

Aisle

Width -

Between Seats - Min.	14"	355 mm
Centre Aisle Ramp	14.5" x 96" x 6"	370 mm x 2,440 mm x 152 mm

Interior Height

Floor to Glass Line

Top (front)	63.5"	1,613 mm
Bottom	31.5"	800 mm
Top (rear)	60.5"	1,537 mm
Bottom	28.5"	724 mm

Entrance Door

Width of Clear Opening	30.0"	762 mm
Height of Clear Opening	84.63"	2,150 mm

Hatches (2) Roof Emergency Escape

Length of Opening	29.0"	737 mm
Width of Opening	19.75"	502 mm

Underfloor Baggage Compartment Volume

Front	102 cu.ft.	2.89 m^3
Centre	105 cu.ft.	2.97 m^3
Rear	155 cu.ft.	4.39 m^3
Total	362 cu.ft.	10.25 m^3

Vehicle Weight (Road Trim)

Net Basic	26,240 lbs	11,927 kg
Payload Capacity (Serviced)	10,260 lbs	4,204 kg
Gross Vehicle Weight	36,800 lbs	17,146 kg

(Includes all road running gear, tires and brakes)

DESCRIPTION OF THE MCI 102A2 BUS FEATURES WHICH ARE RELEVANT TO THE RAILBUS OPERATION

The following descriptions are provided as a guide only, and represent the most recent production practices of the manufacturer. These practices are continually being updated and improved by the manufactures in their efforts to take advantage of the latest technological advances

and therefore the description provided herein will not necessarily describe the precise configuration of the bus at a particular point in time. The descriptions provided herein are therefore subject to change without notice.

SECTION 1: BODY

A. CONSTRUCTION

1. The body is of the integral type with framework of 16 and 18 gauge stainless steel below belt rail and high tensile low allow steel on upper frame. The frame structure is fully welded and properly braced and reinforced for strength and rigidity.

2. All exterior panels are riveted securely to frame members. Dissimilar metals are separated by butyl based tape. The roof and sidewall panel joints are sealed with aluminum pigmented mastic. All steel frame members are dip coated or sprayed with red oxide primer and baked dry prior to assembly.

3. Entire underside of the coach is sprayed with a heavy application of asphalt base undercoating.

4. All fasteners are corrosion resistant.

B. MODESTY PANEL

1. The entrance door modesty panel is molded in medium grey fiberglass reinforced plastic and is installed over a tubular stainless steel frame.

2. A safety pad for passenger protection, of molded self skinned urethane in a medium grey grain finish, is installed on the top of the modesty panel. It is shaped to serve also as a handrail.

C. DRIVER'S PROTECTIVE PANEL

1. A driver's protective panel is installed on the floor to the right of the driver. A curved hand rail of 1¼ inch (32 mm) diameter stainless steel tubing extends from the top of the panel rearward and upward behind the driver to the sidewall. A fiberglass reinforced molded pane is installed behind driver with a protective clear acrylic shield in a stainless steel frame forming the top portion of the panel.

2. Grab rails of 1¼ inch (32 mm) diameter stainless steel tubing are installed on both sides of the entrance stepwell. A horizontal rail is provided on top of the dash.

D. STEPWELL

The entrance stepwell is four steps, constructed entirely from stainless steel. Ribbed stainless steel step nosings with formed risers are provided. Exposed faces at front and rear stepwell are satin finish. All steps are of equal height, 9½ inches (241 mm). All corners are covered for ease of cleaning.

E. SUNVISOR

Three roll-on sunscreens are provided at right and left windshields and at the driver's window. Guide rods, located at each end allow for infinitely adjustable positioning of the screens.

F. INTERIOR REARVIEW MIRROR

An interior rearview mirror, 6 inches x 12 inches nominal size, with a safety canvas backing, is mounted above the upper right corner of the driver's windshield. The bracket permits full adjustment.

G. PARCEL RACKS

A parcel rack with top hinged doors extends over all two-passenger seats providing approximately 106.25 cu ft of storage space. The left parcel rack extends above the driver's area to meet the front inner cap. Reading lights are located underneath the parcel rack in cluster panels which also include the speakers for the P.A. system and the individual gasper for forced ventilation. The gasper and the doors are provided as an option for the Railbus modification. A lockable door is provided above the driver's seat.

H. DOOR CONTROL

A manually operated door control is provided. A handle at the dash convenient to the driver provides over-center control for both open and closed positions. Positive automatic air lock with over-rule is also provided. The air lock is automatically actuated by a microswitch at over-center position when the door is closed. An exterior remote release is provided behind the front target panel. The interior release is located to the right of the driver under the dash overhang.

I. PASSENGER SEATS

1. Seating for the Railbus shall be Canadian Made Wakefield International Seating Incorporated model "Premier".

2. The seats are lightweight, with moulded foam cushions. Arm rests are provided both at wall and aisle side on two-passenger seats. Woven fabric facings on cushions and backs are standard.

3. Two-passenger seats are securely fastened with high tensile tee bolts in high strength aluminum alloy track on wall side and a stainless steel track in the floor. Tee bolts can be readily removed without removing other seats.

4. Seating arrangements - Standard plan accommodates central pedestal only for 102-inch models 49 passenger capacity, consisting of eleven forward facing, two-passenger reclining seats on each side of the coach with a five passenger, non-reclining rear cross seat. For the Railbus, no rear cross seating is provided and an additional row of seats is removed to allow wider spacing between the seats thus resulting in a 40 passenger seat layout.

5. Custom seating arrangements are available. For the Prototype Railbus, two reversible seats will be provided.

J. DRIVER'S SEAT

1. A National Seating Company Model No. 152 fully adjustable, high back seat is provided.

2. The back and cushion is full depth moulded urethane foam.

3. The upholstery and back panel are black vinyl with the seat area perforated for ventilation. Welt cords are goly Mylar.

4. The frame and pedestal are black enamel finish.

K. INTERIOR PANELS

1. The ceiling at the front and the rear window are is color impregnated fiberglass reinforced plastic molded panels. Main ceiling area is vinyl clad aluminum in grey smoke white pattern. Vinyl and aluminum moldings cover panel joints.

2. Lower sidewall trim below windows is grey carpet for the Railbus Prototype. Longitudinal air ducts are stainless steel. Other styles of sidewall covering are available.

3. Body posts between windows are finished in vinyl clad aluminum, to match the ceiling.

4. Risers at the sides of the ramped aisle are stainless steel.

5. The front dash panel, upper portion of the entrance door, and the panel to the left of the driver are fiberglass reinforced plastic. Driver's toe shield is stainless steel.

6. The lower interior covering on the entrance door is a stainless steel kick panel.

7. All trim moldings at floor level are stainless steel or anodized aluminum, covered for corrosion protection and ease of cleaning.

8. Roof and sidewalls are insulated with two-inch (51 mm) resincoated medium density fiberglass, compressed at installation. Condensation drain tubes are provided in the frame. The complete rear lounge seat area is heavily insulated with fiberglass blankets for both heat and noise protection.

Thickness and type of insulation are as follows: the area under the cross seat riser, rear cross seat and ear cross seat back - double thickness of ¾-inch (19 mm) thick, high density AF-545 fiberglass. The surge tank cover panel behind the rear cross seat is one-inch (25 mm) thick foamed polyurethane with Mylar facing. Behind and below the rear simulated window rear is two-inch medium density fiberglass and a ¾ inch thick heavy density fiberglass batt cemented to the inner face of the rear fiberglass panel.

L. FLOOR

1. The floor is flat throughout except for a ramped eight-foot long (2440 mm) aisle section at the front. The floor is ramped three inches (76 mm) higher at the rear. Ramp door at entrance area is approximately 5¾" nominal. Wheel housings do not protrude.

2. The flooring is ½ inch (13 mm) thick five-ply waterproof fir plywood. The center aisle area is reinforced by a second sheet of ½ inch plywood which is glued and stapled to the main floor. The floor is securely attached to the underframe with elevator bolts and self-tapping, countersunk screws. All floor joints are sealed with mastic. The underside of the floor is treated with fire retardant paint.

3. The floor covering is heavy duty quality colored rubber. All joints are butt cut type. The following materials are used:

5/16 inch (8 mm) ribbed, metal backed stepwell tread plates
3/16 inch (5 mm) ribbed entrance area and ramped aisle area (no metal back)
1/8 inch (3 mm) smooth driver's area
1/8 inch (3 mm) smooth center aisle
1/8 inch (3 mm) smooth under seats

4. Continuous length stainless steel seat mounting tracks are securely welded to the coach frame cross members to accommodate the center pedestal for Model 102. The tracks are flush to the top of the floor covering.

M. EXTERIOR MOLDINGS

Black anodized, extruded drip moldings extend along both sides of the entire coach above the window line. Exterior trim moldings are attached to the body to cove the horizontal rivets at both sash and belt lines. Black painted aluminum trim caps cover the window posts. Stainless steel screws and nylon washers are used to eliminate the contact of dissimilar metals thereby preventing corrosion of the moldings. Belt moldings are T-6063 clear anodized aluminum alloy.

N. BUMPERS

1. The front bumper will be removed for the Railbus modification.

2. Extruded dent resistant aluminum rub rails extended along each side of the coach to offer maximum protection to lower body panels from baggage carts and vehicles. The ends are closed with molded rubber caps. The rails are retained with tracked bolts and can be readily removed.

O. MIRROR - EXTERIOR

1. Two fully adjustable exterior rear view mirrors are provided, one at each front corner of the coach. Arms incorporate friction hinges to maintain mirror adjustment. Mirrors may be folded out of the way against coach sides for automatic washing operations. Rubber bumper blocks on the mirror corners prevent

damage when folded against the body. Each mirror is flat, clear plate glass, 8" x 10" (203 mm x 254 mm) for the 102 series.

2. Six-inch (152 mm) round convex mirrors are provided on mounting plates, located above the right hand mirror, and below the driver's mirror, to eliminate blind spots. Mirror heads and arms are black anodized aluminum.

P. FENDERS

1. Molded rubber one piece fenders normally installed at front and rear wheelhousing for A2 models will be removed for the railbus modification.

2. Rear splash aprons are provided with the railbus.

Q. TOW EYES

Hardware for towing and lifting is provided at the front, under the tire compartment trusses. The coach can be lifted by the tow hooks and specified procedure. For the railbus the towbar attachment and lifting eyes will be provided integral with the pilot structure.

R. WINDOWS

1. Seven large passenger side windows are provided on each side of the coach. Each window is double glazed, AS-3 laminated float, heat absorbing safety glass. A 45-inch continuous hinger is provided at the top of the pre-hung sash. The sash may be pushed out for emergency escape by lifting the release bar at the lower edge which disengages the safety latches. Emergency instructions on the metal plates are attached to the release bars at each seat location. All side windows are completely interchangeable except when the coach is lavatory equipped.

2. Double glazed windows are provided for the driver's window and entrance door window for the Railbus.

3. Nominal clear opening glass sizes:

Side Windows - Height - 32.44 inches (824 mm)
- Length - 52.25 inches (1327 mm)
Area of side windows - 164.8 sq. ft. (15.3 m^2)

Driver's Window - Height - 48.75 inches (1238 mm)
- Width at Top - 16.56 inches (420 mm)
- At bottom - 28.37 inches (720 mm)

Entrance Door Window - Height - 32.56 inches (827 mm)
- Width at Top - 17.46 inches (451 mm)
- At bottom - 25.57 inches (649 mm)

Entrance Door Lower Glass - Height - 11.25 inches (286 mm)
- Width - 20.81 inches (528 mm)

Total Clear Glass Area - including windshield - 208.24 sq. ft. (19.34 m^2)

4. Windshield - a large, two-piece curved windshield is provided at the front of the coach. The windshield slopes back 13 degrees and each section has an area approximately 49¾ inches x 47¾ inches (1,263 mm x 1,213 mm). Unmasked clear glass area for each section is approximately 48¾ inches x 46¾ inches (1,238 mm x 1,187 mm). The glass is AS-1 laminated safety tube, Solex Duplate, glazed directly to the body opening with black zipper rubber molding. Windshields are interchangeable from left to right. Destination sign glazing immediately above the windshield consist of ¼ inch Lucite Clear Acrylic with S.A.R. coating on the outside surface.

5. Driver's Window - double glazed fixed, one piece full vision driver's window is provided for the Railbus with black anodized aluminum frame. A small sliding section for signalling and mirror adjustment is provided at the lower rear corner. Glass is AS-2 laminated safety type.

6. Entrance Door Window - a double-glazed fixed, one piece window is provided for the Railbus in the entrance door. Glass is AS-2 laminated safety type. A secondary window is located in the mid-lower section of the door with a visible dimension of 11.25 inches (286 mm) x 20.81 inches (528 mm).

7. Rear Window - a one piece (black painted) molded reinforced fiberglass panel is rivetted to the main structure.

S. BAGGAGE DOORS AND COMPARTMENTS

1. Compartment doors are fully sealed, pantograph, vertical lift type. Each door has a flush-mounted, breakaway type latch handle. Doors are counter balanced with springs for ease of operation and have a safety hold-open latch. Rubber bumpers prevent doors from striking coach body when opened. Each door latch has provision for padlock and customs seals.

2. Three full width underfloor baggage compartments, with a total capacity of approximately 362 cu ft for 102A2 are provided between the front and rear drive axles. Clear opening to each compartment is 33 inches x 54¼ inches (840 mm x 1,385 mm).

3. The compartments are illuminated automatically when the doors are opened. Each compartment is pressurized by the coach heater and air conditioning blowers to help keep out dust and dirt.

T. SERVICE DOORS

1. The left front service door below driver is front hinged and held closed by two quarter-turn, slotted-head fasteners. A two lever over center prop holds the door fully open. Access is provided to auxiliary air tank, parking emergency air tank charging valve, steering components, windshield washer reservoir and air horns.

2. The condenser compartment door is front hinged, piano type, held closed by quarter-turn, slotted-hinged fasteners. Rod type prop automatically holds door when fully opened. Access is provided to the condenser which is mounted on door, and also to the fans' receiver tank, filter/dryer and other air conditioning components.

3. A2 Model - left and right side engine compartment doors are hinged at the top and counterbalanced by a gas spring cylinder. A prop latch arrangement holds the door in the open position.

4. Left and right hand radiator doors are continuous hinged at outer side and are held closed by four slotted-head, quarter-turn fasteners.

5. The blower compartment door is top-hinged and held closed by two spring loaded, slam type latches. A rod type prop can be manually set to hold the door up in the open position.

6. Rear engine compartment doors are outer-side hinged using butt type hinges. Door latches are activated by a paddle type handle. Rod props hold the door in the open position.

7. The surge tank filler door located on the exterior RH side of coach is hinged with a continuous type hinge on the front edge. It is spring loaded.

8. The door for the fuel tank filler is hinged at the top, with a continuous type hinge, and has dual over-center springs to securely hold the door both in the open and closed positions. The fuel tank is removable through the right side body panel opening. This panel is retained at the top by two bolts and at the bottom by a pin arrangement allowing quick access to the fuel tank assembly and drain plug.

9. The voltage regulator is accessed through the rear face of the rear baggage compartment. It is protected by a metal shield.

10. An exterior door located below the driver's window provides access to the main electrical front junction panel. The door is front hinged, with a continuous hinge, and is held in place with two quarter-turn, slotted-head fasteners at the rear. The door is of sandwich construction with a core of foamed-in insulation and is held open by a rod type prop.

11. The battery, air conditioning filter and battery main cutout switch compartment door is top-rubber hinged, held closed by two spring loaded latches activated by a paddle type handle. A manual prop is provided to hold door open.

12. A rear RH service door, with the RH tail light cluster attached is provided to give access to the A.C. Compressor.

13. A rear LH service door with the LH tail light cluster attached is provided to give access to the air cleaner for the Railbus.

U. ENTRANCE DOOR

1. The sedan style door is located ahead of the right front wheel: construction is a welded stainless steel frame with a stainless steel beaded panel riveted on the outside. A fiberglass reinforced panel is used on the inside of the door, with a stainless steel panel on the lower portion.

2. A sturdy hinge casting is used at the top and a plated hinge casting with chrome self aligning ball bearing is used at the bottom of the door.

3. The sash is one piece, fixed, in a black anodized aluminum extruded frame. A secondary window is provided in the mid-lower section.

4. The clear door opening area is 30 inches (760 mm) wide x 84 5/8 inches (2,150 mm) high.

V. SAFETY EQUIPMENT

(See also "Factory Optional Equipment List Provided for the Railbus" on Pages 39-43 of this Appendix).

1. Three spare fuses in a container are mounted to the left of driver on the driver's protection panel.

2. Three reflector triangles in a container are stowed in the right side battery and filter compartment.

W. TOOLS

Standard tools consist of a 12-ton (10,885 kg) hydraulic jack, jack handle, wheel lug wrench and wooden run-up block.

X. MISCELLANEOUS

The following items are standard equipment:

1. A driver's coat hook is provided to left and rear of the driver above the window line.

2. A ring key to operate all slotted head fasteners for compartment doors is located on a hook at left front of the driver's compartment.

Y. WINDSHIELD WIPERS

1. Two heavy duty, air operated Sprague "Air Push II" windshield wipers are installed, one for each windshield. Individual control valves with built-in air pressure regulators are provided on the front dash. The regulators provide constant wiper speed as adjusted by the control valves. Wiper action is not affected by air system pressure variations. Wiper motors are readily removable from the exterior of the coach. Each motor incorporates a two-inch (51 mm) diameter piston and a 5/8 inch (16 mm) diameter drive shaft. Wipers are the "self-parking" type.

2. Wiper arms are pantograph type with 26 inch (660 mm) flexible wiper blades mounted on a 29.5 inch long (749 mm) holder. The wiping arc is 74 degrees and total swept area is 988 sq. in. (6,374 cm^2) each, total 1,976 sq. in. (12,748 cm^2).

3. Sprague "Air Push" air-operated windshield washers with a control button on the dash e provided. The reservoir is located in the left front service compartment. It is polyethylene, five gallon (18.7L) capacity. Two outlet nozzles are located below each half of the windshield. The system is self-purging following each washing cycle.

7. EXTERIOR PANELS

1. Roof Panels - front roof cap and rear crown panel are 1/8 inch (3 mm) thick molded fiberglass and incorporate molded indentations for the marker lights and the Michigan marker lights. Main roof panels are .051 inch (1.3 mm) high tensile aluminum with chromate-free expoxy primer applied to both sides. Panels are pre-stretched on installation and riveted in place with high strength aluminum bucked rivets.

2. Side Panels - flat panels below side windows and above the floor line consist of .081 inch (2.0 mm), pre-stretched primed and polyurethane painted aluminum, securely riveted to the frame structure. Interior aluminum alloy panels are riveted to the frame. A smooth aluminum interior panel is used to provide a continuous airway for the heated or cooled air from the main ducts. The space between inner and outer body panels is filled with fiberglass insulation.

3. Side Panels - beaded - all panels below the floor line are 24 gauge (.6 mm) Satin Blend stainless steel beaded on 4 inch (102 mm) centers.

4. Front Panels - front body panels below the windshield are beaded 24 gauge (.6 mm) Satin Blend stainless steel, securely riveted to the frame. A 20 gauge (1 mm) stainless steel trim panel is provided between and above the headlights. Molded, removable fiberglass trim facia are provided under the windshield and cover access to windshield wipers and door control.

5. Rear Panels - the panel above the floor line is 24 gauge (.6 mm) smooth stainless steel. Lower panels on service doors are beaded 24 gauge (.6 mm) Satin Blend finish stainless steel.

6. Exterior Painting and Lettering - standard exterior painting consist of polyurethane enamel (Imron) applied in two colours to painted areas of coach (aluminum side panels and roof). Paint bands in the same colors may be extended around the front and/or rear of the coach. Standard lettering consists of company name painted on each side of the coach in large letters, or installation of customer supplied pressure sensitive decals, coach numbers 4 inch (102 mm) front, 5 inch (127 mm) rear, white decals or painted in fice locations, and certificate numbers in small letters on each side. Additional colors, deluxe striping, special lettering, can be provided as an option.

AA. FRAME

Understructure A2 - two welded steel structures are provided at the front axle and rear drive axle locations. They are attached to the coach understructure and form the base for air suspension springs. Those at the rear also connect to the engine-transmission cradle rails which extend rearward. Aluminum bulkheads are provided between baggage compartments and form bays for heat and air conditioning equipment, fuel tank, batteries, etc. A stainless steel bulkhead is provided at the front axle area.

SECTION 2: BRAKES

A. CONTROLS

The brake application valve is a Bendix-Westinghouse type E-10. Rear brake relay valve is a Bendix-Westinghouse type R-12.

B. AIR SYSTEM

1. The air compressor is a Bendix-Westinghouse "Tru-Flo 700", two cylinder, fully unloading type. Output is 15.5 cfm (.44 m 3/m)

at 1250 engine rpm. The compressor is flange mounted on the engine, driven by the rear left engine camshaft. The engine provides oil lubrication and water cooling for the compressor. Between the compressor and air discharge muffler (ping tank) is a flexible steel wound discharge line. A governor is provided to load and unload the compressor to maintain correct operating pressures.

The majority of the air system components are Bendix-Westinghouse. Four air reservoirs consisting of one wet tank, capacity 2,059 cu. in. (33, 740 cm^3), one dry tank 2,357 cu. in. (38,620 cm^3) capacity, one auxiliary tank 815 cu. in. (13,355 cm^3) capacity, one emergency air tank 2,059 cu. in. (33,740 cm^3) capacity for a total of 7,390 cu. in. (119,460 cm^3). A Bendix-Westinghouse air dryer is standard equipment. Each air tank and ping tank is equipped with a readily accessible manual drain cock for servicing. The first air tank includes a pressure safety valve set at 150 PSI (1,034 kPa).

2. A one-way check valve, located between the first and second tanks, adjacent to second tank, prevents loss of service brake air pressure. A second tank (dry) supplies the service brake system with air. A pressure-protection valve is provided between the service brake air system (second tank) and all other air system components. The valve remains closed until air pressure in second tank exceeds 65 PSI (488 kPa) to assure fast buildup of service brake air. The valve also acts as a one-way check should failure occur in the air system beyond the second tank. The parking emergency reservoir is fully protected from balance of air system by a one-way check valve. Filters and regulator valves are provided in auxiliary air systems for such air operated devices as suspension, wipers, door lock, horn, etc.

3. The low air pressure warning system consists of a tell-tale light and buzzer at the driver's position. A three-inch (76 mm) round air pressure gauge is also provided in the instrument panel. These devices indicate air pressure in the service brake air tank.

NOTE: In A2 the air tanks (wet, dry and emergency) are located in the engine compartment away from the road splash.

SECTION 3: COOLING SYSTEM

A. RADIATORS, BLOWERS AND SHUTTERS

Two radiators, mounted on each side of the coach above the engine are provided. Cores are of fin and tube construction with six rows of oval tubes, each 3/32 inch x $\frac{3}{4}$ inch (2.4 mm x 19.1 mm). Dual centrifugal blowers, belt driven from the engine crankshaft through a special gear box, pull outside air through the radiators into the sealed, insulated blower compartment when the air operated, thermostatically controlled shutters are open.

When engine coolant is below normal operating temperature the shutters are automatically closed. When they are closed, no air is pulled across the radiators and the horsepower required to drive the blowers is significantly reduced. Blower gearbox include a sight gauge for checking the lubricant level and an easily accessible oil filler tube. Belt tension is maintained through an automatic air controlled belt tightener.

B. SURGE TANK

The surge tank is mounted in the upper blower compartment. Coolant filler neck and pressure release valve are mounted behind the access

door on the right rear side of the coach. A coolant level check can be done rapidly by means of a sight glass installed on the surge tank.

C. THERMOSTATS AND ALARMSTATS

180 degree F thermostats and 210 degree F alarmstats are installed at the front of each cylinder head.

SECTION 4: ELECTRICAL

A. STARTING MOTOR

A 24 volt Delco-Remy starting motor is provided. Shift lever and solenoid plunger are totally enclosed for protection from the elements. The clutch is ratchet type with "Positork" drive. The pinion meshes with the ring gear on the flywheel by the action of the starter solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. The clutch disengages only when the solenoid circuit is interrupted; this protects the pinion and ring gear from damage. The engine may be started from the front or rear of the coach and a safety switch in the engine compartment is provided to prevent starting engine from either location during maintenance. A fuel pressure sensing switch interrupts the starter circuit to prevent starter engagement once engine is running.

B. ALTERNATOR

A Delco-Remy 24 volt, 270 amp, self rectified alternator is mounted at the right side, rear of engine. The alternator is driven by a gear on the right engine camshaft. Nominal output at various engine speeds is as follows: 170 amperes at idle (550 engine RPM), and 245 amperes at 900 engine RPM (fast idle). The alternator is of brushless design, air cooled. All current carrying conductors are stationary.

The only moving part is the rotor, which is mounted on two ball bearings. A transistor type Delco-Remy voltage regulator is provided in a covered area at the left upper corner of the #3 rear right hand baggage compartment. Voltage is controlled electronically. The regulator has no moving parts that may be affected by temperature or humidity. Adjustment is through a readily accessible external screw.

C. HORNS

An optional air horn is provided for the Railbus.

D. LIGHTING

1. Interior Lights - All lamps are 24 volts as follows:

   a. Entrance Stepwell - Two 6 C.P. bulbs are located to provide full illumination of the entrance step area. The light is "ON" automatically whenever the entrance door is open and the "chime and stepwell" circuit control switch located left of the driver is "ON".

   b. Driver's Light - Provided above driver, the fixture is built-in type with two separate adjustable lamps with 6 C.P. bulbs controlled by a switch at right of driver.

   c. Instrument Panel - Indirect illumination is provided wit a rheostat control fed from the marker light circuit.

   d. Indirect Overhead - A three position switch located on the right wing of the instrument panel controls two levels of interior illumination. In the "Off" position all tubes are off. In the "Window" position, only the 18 fluorescent tubes y the windows are illuminated. In the

"Indirect" position, 20 fluorescent tubes (30 watt each) located overhead at each side of the central ceiling are operated together with 18 fluorescent tubes (30 watt each) located at the windows.

e. Reading Lights - Provided for each passenger position except the center position of the rear cross seat. The lights are individually controlled, prefocused and directional for each position. The lamps are mounted in housings under the parcel rack and can be relocated for various seating configurations. With marker lights "ON" the reading light circuit is energized.

f. Aisle Lights - Six 6 C.P. bulbs are provided as aisle lights, mounted under the aisle end of the first, second, fourth, sixth, ninth and eleventh left hand seats of the standard 49 passenger seating plan. These bulbs are also connected to the marker light circuit.

g. Baggage Compartments - Each is automatically illuminated when its door is opened. Six 21 C.P. bulbs are provided. Individual switches at each baggage compartment door control one lamp.

h. Engine Compartment - Illuminated by four 3.5 C.P. bulbs controlled by a switch in engine compartment.

2. Exterior Lights

a. Headlights - Four 12 volt rectangular sealed beam Halogen lamps installed as dual units on each side at front of coach. Outer lamps have upper (high) and lower (dim) beams. Headlamps are controlled by a switch on the panel to the left of the driver. Headlamps, clearance and I.D.

lamps are interconnected so that they are illuminated when the headlights are "ON". A foot switch is provided for selection of upper and lower headlight beams. All exterior lamps are 24 volt. Master switch must be on before headlamps can be illuminated.

E. REFLECTORS

The standard coach is equipped with reflectors to comply with DOT safety regulations. Reflector locations and colors are as follows:

Location	Color	Shape
On each side front	Amber	Rectangular
On each side near coach mid-point	Amber	Round
On each side near rear	Red	Round
On each side rear	Red	Rectangular

F. PASSENGER SIGNAL CHIME

An electrical passenger signal chime is activated by a red call button switch located at each reading light cluster under the parcel rack. A driver's switch is provided to make the chime inoperative.

G. BATTERIES

Two 12 volt batteries, multiplate, storage lead acid type SAE J537 No. 8D900 Ref. 20T8A, connected in series, are provided to supply 24 volts for all electric components. (Headlights are on a 12 volt system.) The coach electrical system is negative ground. Batteries are mounted side-by-side in a separate compartment forward of the baggage compartments on the right hand side. The battery compartment consists of corrosion resistant material, utilizing

stainless steel and fibre reinforced polyester throughout. The battery disconnect switch is located in a protected area accessible through the battery compartment door.

H. CIRCUIT BREAKERS

All circuits except the evaporator and condenser motors are protected by automatic reset circuit breakers located in the electrical junction box at the left front exterior of the coach below the driver's window. They are accessible through an access door held closed by two quarter-turn fasteners. The main circuit is 105 amp automatic reset type which along with the evaporator blower motor circuit (80 amp manual reset type), and condenser fan motor circuit (105 amp manual reset type) are conveniently located in the front left hand baggage compartment in the A/C Junction Box.

I. WIRING

Stranded copper wiring with cross-linked polyethylene plastic insulation assembled in a loom-covered harness is used throughout the coach. The wiring has special insulation (single conductor low tension automotive thermoplastic setting, type SXL SAE J878A) for protection from heat, oil and fuel. In addition, engine harnesses are encased in conduit. All harnesses are securely held in place by rubber covered clips and grommets. Spare wires are provided in main harnesses for additional circuits with wires dead-ended at the junction box left of driver, left side air conditioning junction panel, and at rear engine compartment junction panel. All wires are number coded and color stamped for identification. Relays are used where necessary to eliminate long runs of heavy wires. Each light is grounded by a wire to the lamp socket where applicable. Some sockets are direct grounds.

J. FRONT INSTRUMENT PANEL

1. The front instrument panel is a one piece unit with recessed gauges. The panel is angled to minimize reflections and enhance driver viewing.

2. A bank of tell-tale lights is provided in two clusters on each side of the instrument panel. Tell-tales with buzzers as noted indicate the following conditions:

Condition	Tell-Tale Light	Tell-Tale Color	Audible Alarm
Headlamp High Beams "ON"	Hi-Beam	Blue	None
Engine Overheated	Hot Eng.	Red	Buzzer
Engine Oil Pressure Low	Low Oil	Red	Buzzer
Engine Coolant Low (Opt)	Low Water	Red	Buzzer
Air Pressure Low	Low Air	Red	Buzzer
Parking Emergency Brake On	Emerg. Brake	Red	None
A/C Malfunction	A/C Hi-Low	Amber	None
Back-up Light "ON"	B.U. Lite	Green	None
Alternator Not Charging	Not Gen.	Red	None
Heater Water Valve Open	Heat	Green	None

3. Gauges provided in the main panel consist of the following:

   a. Three-inch (76 mm) electronic speedometer reading 0 to 80 mph (0 to 129 km/h). Speedometer dial is also calibrated in kilometers.

   b. A 3 3/8 inch diameter (86 mm) mechanical air pressure gauge reading 9 to 150 psi (1,034 kPa). Gauge indicates pressure of second (service brake) air tank.

c. Electrical engine oil pressure gauge reading 0 to 80 pis (552 kPa).

d. Electric engine coolant temperature gauge reading 100 degrees to 250 degrees F (38 degrees to 120 degrees C).

e. Removable dummy plugs are provided to accommodate optional fuel level gauge and voltmeter when specified.

f. Gauges have white letters with black background, with tan inner dial and persian orange marker. All gauges are indirectly illuminated and a rheostat switch is provided to control intensity of illumination.

4. Immediately below the face of the instrument panel at the right of the steering column are left-hand and right-hand air operated windshield wiper control rotating knobs and the air operated windshield washer control pushbutton.

5. Optional P.A. system controls are at immediate left of the steering column. All other switch controls are conveniently mounted on panels at either side of the instrument panel. The switch panels include space for optional switches. The following standard controls are properly marked as to function.

K. RIGHT PANEL

1. Steplight and chimes (On-Off).
2. Interior Light (Indirect-Off-Window).
3. Driver's Light (On-Off).
4. Headlamp (On-Off). When "On", this switch also energizes the circuit controlled by switch 4. Master control switch must be "on" for headlights to function.
5. Provision for six optional switches.

L. LEFT PANEL

1. Engine Start (momentary "On").
2. Master Control (On-Off).
3. Emergency Stop (On-Off with guard).
4. Passenger A/C and Heat Selector (A/C-Off-Heat).
5. Driver's Defroster Fans (Lo-Off-High).
6. Driver's A/C (On-Off).
7. Fast Idle (On-Off).
8. Provision for five optional switches.

M. LEFT SIDE PANEL

1. Coach heat rheostat.
2. Gauge illumination rheostat.
3. Dash illumination rheostat.
4. Radio (mounted inside the arm rest at rear of side panel).
5. Provision for four optional switches.

SECTION 5: ENGINE

A. POWER PLANT

The powerplant is mounted longitudinally at rear of coach: engine, clutch, and transmission are mounted on a cradle. The cradle is attached to dual support rails to facilitate powerplant removal. Engine and transmission mounts are resilient rubber. In additional to service doors, removable access panels are provided at the rear cross seat area providing excellent service accessibility for normal maintenance procedures. A remote control panel with service light switch, emergency stop button, remote control switch, and engine run switch are provided in the engine compartment. In addition, oil pressure gauge, water temperature gauge, and "no generator" tell-tale lights are provided in the engine compartment.

B. ENGINE

1. A Detroit Diesel Vee-Type, 2 cycle model 6V-92TA engine is provided.

SECTION 6: FUEL AND INTAKE

A. FUEL TANK, FILLER AND INTAKE

A welded aluminum 156 gallon fuel tank (148 gallon at 95% capacity) for the 102A2 is provided behind the front axle ahead of the battery compartment. The filler neck is on the right side of the coach and a fuel tank drain plug is provided at bottom of tank. A bayonet type filler neck cap is provided. A anti-spill device and whistle to indicate when tank is 95% filled are incorporated. Dual fuel filters, one sock type, one paper type, both spin-on, are located on the right side engine mounting rail, conveniently accessible for servicing. A manual shut-off valve is provided to prevent siphoning of fuel when filters are being serviced.

B. AIR INTAKE AND FILTER

The air intake for the engine is located above the left radiator screen in a turbulence free zone, away from any road splash. Air enters a pre-cleaner (cyclone) to separate moisture and heavy contaminants prior to entering a horizontal dry type air cleaner. The filter is easily accessible from the rear left service door. A filter restriction indicator is above the remote control box in the engine compartment.

SECTION 7: SUSPENSION

A. DESCRIPTION

1. Full air suspension is provided at each axle to absorb vertical loads on axles and to maintain constant vehicle height regardless of load (except for tire deflation).

2. 96A2, 102A2 and 102A3 front axles are equipped with two rolling lobe type air springs 12.6 inches (320 mm) diameter and one height control valve. Rear drive axle is equipped with four rolling lobe type air springs, (12 inches in diameter) (305 mm) and two height-control valves.

   An anti sway bar is included on all drive axles.

3. A delay feature in the height control valves prevents excessive air usage when axles travel over slight irregularities.

B. RADIUS RODS

The position of the front and rear drive axles is maintained at each location by four heavy duty rubber bushed radius rods. A transverse stabilizing rod is also provided at the front axle to assure correct positioning of the axle at all times. Silent block molded sleeve bushings are used in the 102A2 suspension.

C. SHOCK ABSORBERS

Double acting telescopic shock absorbers are provided, one at each side of the front axle, two at each side of the rear drive axle. All shock absorbers are interchangeable.

SECTION 8: TRANSMISSION

An Allison Automatic HT-740D Transmission with a TC497 torque converter will be provided for the Railbus. The TC497 torque converter provides lock-up in the top gears to enhance fuel economy.

SECTION 9: PROPELLER SHAFT

Power is transmitted from the transmission to the rear axle via a heavy duty propeller shaft with Dana 1710 Series needle bearing universal joints. A guard is provided, to retain the shaft, as a safety feature.

SECTION 10: HEATING AND AIR CONDITIONING

A total heating and air conditioning system, integrated to the maximum possible extent, is standard equipment.

A. HEATING SYSTEM

1. The main underfloor unit immediately ahead of the front baggage compartment contains ducting, filters, heater core, evaporator and centrifugal type blowers. Oval slotted inlets on the left side of the coach, below the first side window, admit fresh air to the underfloor plenum. Fresh air is introduced into the coach heating and cooling system and makes up 10% of the recirculated air. Recirculated air is drawn back into the plenum through screened openings in the aisle ramp riser near the front of coach on both sides and through a series of slots at the extreme front and rear of both distribution ducts. All air passes through a washable filter before moving through openings in the entrance door. The interior of the coach is slightly pressurized when the blowers are on.

2. The front dash unit consists of ducting, heater-defroster core, evaporator and dual two-speed blowers. Protected inlets under the driver's floor admit fresh air to the front dash unit. Driver's control on the floor to left of the driver is provided to allow switching from outside air to full recirculated air. Recirculated air is drawn though a screened opening on the right hand face of the dash across the evaporator, then on to the heater core, blowers and distribution system. Fully adjustable driver's vents are provided on each side of the instrument panel. Defroster outlets at the base of the windshields are located so as to keep the entire windshield free of frost and fog.

3. In addition to dampers noted above, the following controls are provided:

   a. A three position switch with "heat", "off" and "air condition" positions to control the main underfloor system.

   b. A rheostat control switch provides a 10 degree F adjustment range of interior temperature thermostat settings.

   c. A two position toggle switch with "off" and "air condition" positions controls the front dash air conditioning. When "on" dash blowers are automatically on low speed.

   d. One three position (off-hi-lo) switch controls the front dash blowers for defrosting, heating and air conditioning.

   e. The driver's water heater valve located on the floor to left of the driver is manually adjustable to regulate the flow of water to the front dash heater - defroster core.

f. Manual gate valves are provided in the engine compartment to shut off the flow of all water to heater cores.

4. Coach interior temperature is automatically controlled by the main underfloor system for both heating and air conditioning. Additional conditioned air with manual control is provided by the front dash unit.

5. An electrically operated water valve, and a mercury tube sensing unit thermostatically control the flow of water to the underfloor heater core. The water valve opens and closes automatically on demand of the sensing unit which is located in the return air duct, in #1 left hand baggage compartment to satisfy the temperature setting called for by the position of the driver's rheostat switch. Since the engine radiators and surge tank are mounted well above the coach floor line, only gravity and the engine water pump are required to provide ample flow of water to the heater cores. Water flow to the front dash heater core is not affected by the opening and closing action of the electric water valve on the main system.

B. AIR CONDITIONING SYSTEM

1. A six cylinder compressor (Carrier 05G) is mounted in the engine compartment, driven directly from the main power plant through dual steel cord belt drive. Belt tension is automatically maintained by an air controlled tightener. The compressor loads and unloads automatically to provide the correct amount of cooling capacity. An electric clutch is provided at the compressor to disengage the engine drive when air conditioning is not required, and subsequently eliminate parastic power losses.

2. The condenser fan assembly includes a two H.P. (1.5 kw), 24 volt motor, with shrouded axial fan. The fan is on only when the air conditioning switch is "ON". Condenser and fan are mounted on the left side of the coach at the rear of the front wheel housing. The condenser coil has copper tubes for maximum efficiency. Receiver tank, filter-dryer and other air conditioning components are mounted in the same compartment.

C. SYSTEM CAPACITIES

1. Main underfloor blowers are centrifugal type driven by a single speed, twin shaft 1½ H.P. (1.1 kw), 24 volt motor. When control switch is on "heat" or "air conditioning", fan output is 2700 cfm (76.4 m^3/min).

2. Dual front dash blowers are centrifugal type, driven by individual 24 volt motors. The speed selector allows for 500 cfm (14.1 m^3/min) output on "high" and 250 cfm (7.0 m^3/min) output on "low" position.

3. Heater capacities based on 180 coolant degrees F (82 degrees C) water glycol solution, 70 degrees F (21 degrees C) coach temperature, are 154,000 BTU/hr (45.1 kw) for underfloor system and 34,200 BTU/hr (9.96 kw) for front dash system.

4. Main underfloor air conditioning system capacity is 132,000 BTU/hr (38.7 kw).

5. A one ton, 12,000 BTU/hr (3.52 kw) air conditioning evaporator is an integral part of the driver's unit.

6. Total system capacity is nominal 12 tons or 144,000 BTU/hr (42.19 kw).

7. Outside ram air ventilation is provided to the driver's area through a "gasper" type adjustable inlet located left of the steering column under the dash.

FACTORY OPTIONAL EQUIPMENT LIST PROVIDED FOR THE RAILBUS

The following items are included in the baseline vehicle as factory supplied options:

BODY

- Chemical type lavatory with washbasin facility
- Thermal drain valve
- Air closer on lavatory door

SASH

- Double glazed full vision driver's sash
- Double glazed entrance door sash
- Double glazed grey side passenger sash.

MISCELLANEOUS

- Driver's clear acrylic panel and night curtain
- Parcel rack compartment doors w/o dividers

SAFETY EQUIPMENT

- 17 lb general fire extinguisher - replacing standard
- 20" fire axe
- 36 unit first aid kit

EXTERIOR

- Deletion of paint from rear of coach starting at front edge of radiator screens
- Blank target panel (front panel below windshield).
- Retractable step
- Added insulation at front of coach

NAMEPLATES & DECALS

- English/French Emergency Exit instructions
- English/French Nameplates - Decals

CARD HOLDERS AND TICKET BOXES

- Ticket box mounted left of driver

KEYLOCKS (Exterior)

- Junction box door with keyed alike lock
- (6) Baggage doors all with keyed alike locks
- Sedan entrance door with keyed alike lock
- Battery door with keyed alike lock
- Front side service door with keyed alike lock
- Fuel fill door with keyed alike lock

MIRRORS

- Heated exterior rear view mirrors

VENTILATION & AIR CONDITIONING

- Parcel rack mounted power ventilation system
- Heated air supply in stepwell

ELECTRICAL

- In-station lighting - Option 2
- Entrance area light above stepwell

INSTRUMENTATION

- Fuel level gauge
- Voltmeter
- Sigmanetics electric engine tachometer
- Engine hour meter installed in engine compartment

RADIO & PA

- CB radio 12 volt power source and plug-in
- Motorola two-way radio antenna plus provision for second antenna
- AM/FM radio + PA

CONTROLS AND ALARMS

- Low level coolant level sensor (warning only)
- Thermal time delay
- Automatic back-up warning horn

IMMERSION HEATERS

- Immersion heater provisions
- Immersion heater - lavatory retention tank
- Immersion heater - engine oil pan
- Immersion heater - engine block
- Conventional 3 prong plug receptacle (110 V)

MISCELLANEOUS ELECTRICAL

- Cruise Control

MECHANICAL

- Air compressor with heavy duty steel rods
- Air horn with foot valve

ENGINE COOLING SYSTEM

- Engine cooling dampers

ENGINE RELATED ACCESSORIES

- Oil reserve tank
- Engine, transmission underpans
- Two-speed governor
- DDA 6V92TA Engine - 307 HP

FUEL SYSTEMS

- Auxiliary Fuel Tank
- 192 US gallon fuel (total fuel capacity including main tank)

MISCELLANEOUS MECHANICAL ITEMS

- Allison Automatic HT-740D Transmission with TC497 Torque Converter (fuel economy model)

SEATING

- Wakefield International Seating Inc., in 40 passenger arrangement (i.e., 3 rear seats eliminated from the 43 seat arrangement)
- Trim rear seat area
- Two reversible seats.

BUMPERS & RUB PARTS

- Bumper rub rail - rear bumper
- 5" rubber rub rail on basic aluminum extrusion

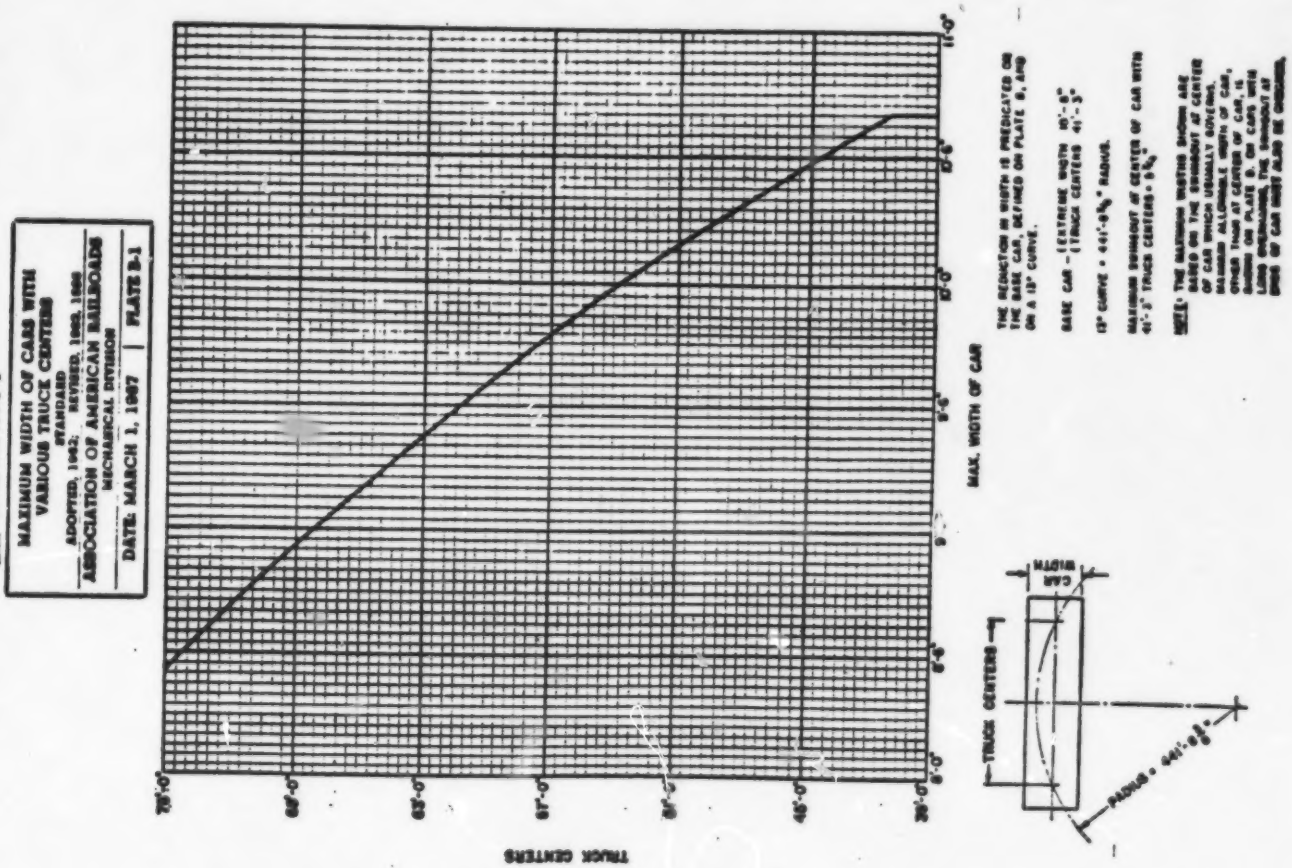
MISCELLANEOUS ITEMS

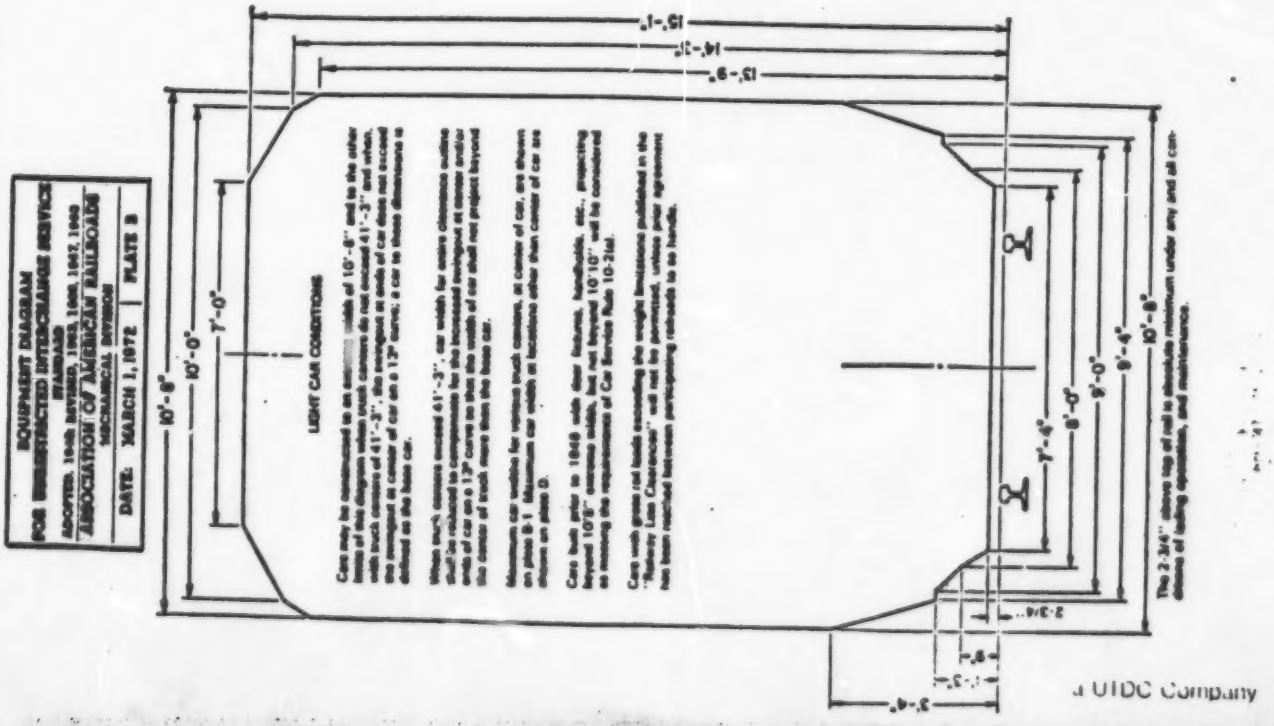
- Sound barrier between passenger seat area and engine compartment
- Omit destination sign curtain, rollers, and mechanism
- Separate switch for reading lights
- Cigarette lighter mounted on left-hand side of dash
- Delete wet towel dispenser from lavatory
- Wet type wiper arms
- Relocate air cleaner to face backwards
- Left-hand access door similar to right-hand A/C compressor door
- Cut down left-hand driver's armrest
- Carpet lower interior sidewalls

APPENDIX II

AAR PLATE B, B-1

CLEARANCE ENVELOPE


MAXIMUM WIDTH OF CARS WITH VARIOUS TRUCK CENTERS
STANDARD
ADOPTED, 1942; REVISED, 1955, 1966
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION
DATE: MARCH 1, 1967 | PLATE B-1
NOTE: FOR USE WITH PLATE "B"
MAX. WIDTH OF CAR
TRUCK CENTERS
THE REDUCTION IN WIDTH IS PREDICATED ON THE BASE CAR, DEFINED ON PLATE B, AND ON A 13° CURVE.
BASE CAR — (EXTREME WIDTH 10'-8"
(TRUCK CENTERS 41'-3"
13° CURVE = 441'-8½" RADIUS.
MAXIMUM OVERHOOT AT CENTER OF CAR WITH 41'-3" TRUCK CENTERS = 5¾"
SEE: THE MAXIMUM WIDTHS SHOWN ARE BASED ON THE OVERHOOT AT CENTER OF CAR WHICH USUALLY GOVERNS. BECAUSE ALLOWABLE WIDTH OF CAR, OTHER THAN AT CENTER OF CAR, IS LESS RESTRICTED, THE OVERHOOT AT ENDS OF CAR NEED ALSO BE CHECKED.
CAR WIDTH
TRUCK CENTERS
RADIUS = 441'-8½"


EQUIPMENT DIAGRAM
FOR RESTRICTED DITECHANGE SERVICE
STANDARD
ADOPTED, 1948; REVISED, 1955, 1958, 1962, 1969
ASSOCIATION OF AMERICAN RAILROADS
MECHANICAL DIVISION
DATE: MARCH 1, 1972 | PLATE B
LIGHT CAR CONDITIONS
10'-8"
10'-0"
7'-0"
15'-1"
14'-2"
13'-9"
12'-6"
9'-4"
8'-0"
5'-0"
3'-6"
2-3/4"

APPENDIX III

CONDENSED FRA TRACK SAFETY STANDARDS

TABLE 1: CONDENSED FRA TRACK SAFETY STANDARDS FOR TANGENT TRACK

Parameters	CLASS OF TRACK					
	1	2	3	4	5	6
Operating Speed Limits						
Freight	10 mph	25 mph	40 mph	60 mph	80 mph	110 mph
Passenger	15 mph	30 mph	60 mph	80 mph	90 mph	110 mph
Gage						
At least	4'8"	4'8"	4'8"	4'8"	4'8"	4'8"
But not more than	4'9¾"	4'9½"	4'9½"	4'9¼"	4'9"	4'8¾"
Alignment						
Deviation of mid offset of 62 ft line not more than	5"	3"	1¾"	1¼"	¾"	½"
Track Surface						
Deviation from uniform profile, either rail, midordinate of 62 ft chord not more than	3"	2¾"	2¼"	2"	1¼"	½"
Deviation from zero cross level at any point on tangent not more than	3"	2"	1¾"	1¼"	1"	½"
Difference in cross level between any two points less than 62 ft apart on tangents not more than	3"	2"	1¾"	1¼"	1"	5/8"

TABLE 2: CONDENSED FRA TRACK SAFETY STANDARDS FOR CURVED TRACK

Parameters	CLASS OF TRACK					
	1	2	3	4	5	6
Operating Speed Limits						
Freight	10 mph	25 mph	40 mph	60 mph	80 mph	110 mph
Passenger	15 mph	30 mph	60 mph	80 mph	90 mph	110 mph
Gage						
At least	4'8"	4'8"	4'8"	4'8"	4'8"	4'8"
But not more than	4'9¾"	4'9¾"	4'9¾"	4'9½"	4'9½"	4'9"
Alignment						
Deviation of midordinate of 62 ft chord not more than	5"	3"	1¾"	1½"	5/8"	3/8"
Track Surface						
Run off in any 31 ft of rail at end of a raise not more than	3½"	3"	2"	1½"	1"	½"
Deviation from designated elevation on spirals not more than	1¾"	1½"	1¼"	1"	¾"	½"
Variation in cross level on spirals in any 31 ft not more than	2"	1¾"	1¼"	1"	¾"	½"
Deviation from zero cross level at any point from designated elevation on curves between spirals not more than	3"	2"	1¾"	1¼"	1"	5/8"
Difference in cross level between any two points less than 62 ft apart on curves between spirals not more than	3"	2"	1¾"	1¼"	1"	5/8"

Transportation Technology Limited

Project: Advanced Railbus — Title: Design Specification Appendix III

Report No. 339-410-001

Date: 86.05.28 — Issue: 2 — Page: 3 of 3

By: P.E.T. — Appd:

APPENDIX IV

APPLIED LOADS AND CONDITIONS

DETAILED MASS ESTIMATES

SECONDARY SPRUNG (BODY MOUNTED)

	Rear Axle (kg)	Front Axle (kg)	Total (kg)
Road Suspension Removed as Delivered Bus Empty Plus Snow Plow (2)	5921 + 500	3944 + 500	9865 +1000
TOTAL RAILBUS BODY TARE MASS (empty)	6421	4444	10865
Capacity (passengers and baggage)	2564	1640	4204
Railbus Gross Body Mass (Fully Loaded Condition)	8985	6084	15069

PRIMARY SPRUNG (SUBFRAME MOUNTED)

	REAR SUBFRAME (kg)	FRONT SUBFRAME (kg)
Subframe	240	240
Tread Brake Unit 120 kg each	240	240
Gearbox	305	0
Drop Box	200	0
Coupling (one half) 40	20	0
Suspension/rods	100	100
TOTAL PRIMARY SPRUNG MASS	1105	580

UNSPRUNG (AXLE MOUNTED)

		REAR AXLE (kg)	FRONT AXLE (kg)
Axle		206	206
Wheel (2)	277 each	554	554
Bearings Units	16 each	32	32
Bearing Housings	40 each	80	80
Primary Springs	26/set	52	52
Coupling (one half)		20	0
TOTAL UNSPRUNG MASS		944	924

STATIC FORCES ACTING AT SUSPENSION POINTS DEFINED

Vertical Forces (Z-direction)

a) Loading of secondary springs at rear truck subframe (4 airbags).

Static

$$Z_{S.R.} = \frac{\text{Static Mass} \times 9.81}{4}$$

*Tare

$$Z'_{S.R.} = \frac{6421 \times 9.81}{4} = 15.7 \text{ kN (per spring)}$$

*Gross

$$Z''_{S.R} = \frac{8985 \times 9.81}{4} = 22.0 \text{ kN (per spring)}$$

Note:

1) Roll stiffness is partially provided by two point leveling at the rear subframe. This is accomplished by pneumatically connecting the air bags on the right side of the frame together and providing a leveling valve which controls the height of that side of the bus only.

The two airbags on the left side of the bus are similarly connected together and levelled.

2) Non-symmetrical positioning of the airbags over the axle centreline results in a net moment applied to the rear subframe which is reacted by the traction rods.

*Note: In this load summary, tare loads are marked ' and gross loads are marked ''.

b) Loading of secondary springs at front truck subframe (2 airbags).

Tare

$$Z'_{S.F.} = \frac{4444 \times 9.81}{2} = 21.8 \text{ kN (per spring)}$$

Gross

$$Z''_{S.F.} = \frac{6084 \times 9.81}{2} = 29.8 \text{ kN (per spring)}$$

Note: The airbags at the front truck are connected together and leveled at a single point.

c) Loading of primary springs at rear truck subframe (2 Chevron pairs)

Static

$$Z_{P.R.} = \frac{\text{Static Mass} \times 9.81}{2}$$

Tare

$$Z'_{P.R.} = \frac{(6421 + 1105) \times 9.81}{2} = 36.9 \text{ kN}$$

Gross

$$Z''_{P.R.} = \frac{(8985 + 1105) \times 9.81}{2} = 49.5 \text{ kN}$$

d) Loading of primary springs at front truck subframe (2 Chevron pairs)

Static

$$Z_{P.F.} = \frac{\text{Static mass} \times 9.81}{2}$$

Tare

$$Z'_{P.F.} = \frac{(4444 + 580 \times 9.81}{2.0} = 24.6 \text{ kN}$$

Gross

$$Z''_{P.F.} = \frac{(6084 + 580) \times 9.81}{2.0} = 32.7 \text{ kN}$$

LOADING CONDITIONS (INCLUDING DYNAMIC FACTORS)

ULTIMATE LOADS (ASSUME EXTREME VEHICLE LOADING)

CASE:1 (COMBINATION OF)

- Vertical secondary ($Z_{S.R.}$ & $Z_{S.F.}$) 1 ± 1g
- Extreme vertical passenger and baggage load plus snow and ice equal to 76.0 kN
  (i.e., $Z_{S.R.}$ ultimate = 2 x ($Z'_{S.R.}$ + 76 x .6) per spring)
- Lateral traction rods $Z_{T.LAT}$ ±1g
  At upper diagonal rods

CASE: 2

- Longitudinal Load — 230 kN
  Applied to subframe as a result of derailment

PROOF LOADS (ASSUME GROSS VEHICLE LOADING)

CASE: 1 (COMBINATION OF)

- Vertical (at secondary) — 1 ±.50g
  (i.e., $Z_{S.R.}$ proof = 1.50 x $Z''_{S.R.}$ Static)

- Lateral (at secondary/traction rods) — ±.3g

CASE: 2

- Jacking load - i.e., can jack up bus at any point on the main structure of the subframe without causing yielding to occur.

FATIGUE LOADS (ASSUME 100% LOADED CAPACITY)

CASE: 1 (COMBINATION OF)

- Vertical (Secondary) ± 1.5 m/s^2 ($Z_{S.R.}$ & $Z_{S.F.}$)
  i.e., $Z_{S.R.\ max} = Z''_{S.R.} \times 1.15$
  $Z_{S.R.\ min} = Z''_{S.R.} \times .85$

Plus: 50 m/s^2 vertical acceleration of the subframe and primary sprung components due to track input.

- Lateral ± 1.5 m/s^2 acceleration of secondary sprung mass plus ± 20.0 m/s^2 lateral acceleration of primary sprung mass.

CASE: 2

- Longitudinal ± 2.0 m/s^2 braking and propulsion loads.

OTHER LOADS & CONDITIONS

BRAKING & PROPULSION FORCES (Proof) ±4 m/s^2

The torque loads on the subframe resulting from braking and propulsion are reacted by the traction rods.

WIND FORCES (600 N/m^2)

Based on: $P = \frac{F}{A} = \frac{1}{2} \times D \times Cd \times V^2$

where D = 1.2 kg/m^3

Cd = .8

V = 35 m/s

- bus length = 12.147 m
- bus height = 3.370 m

Side Wind Load = area x pressure

= 12.147 x 3.370 x 600

= 24.6 kN

CENTRIFUGAL FORCE IN CURVES ±1 m/s^2 in both left and right curves.

SAFETY FACTORS

For the purpose of determining the allowable loads applied to the subframe, assume the following safety and material design factors.

Loading	Factor	Material Property
- Ultimate	2.2	Ultimate Tensile Strength
- Proof/Yield	1.5	Yield Strength
*- Fatigue	1.5	Endurance Limit
- Buckling	1.8	Yield Strength

*Note: Fatigue factors such as surface, notch sensitivity, stress concentration, etc. must be applied to resulting stress levels as applicable.

MATERIAL

The following low carbon steels will be used.

	Material
- Standard Hollow Structurals	CSA G40.21 Grade 50 W
- Plates/Fabrications	CSA G40.21 Grade 44 W

ATTACHMENT A-4

RESULTS OF DESIGN

REVIEW

K6-10491

ATTACHMENT A-4 - RESULTS OF DESIGN REVIEW

LISTING

A-4-1	Minutes of Meeting - Review Session Phase I Interim Report For The Design and Development of the Canadian Advanced Railbus.
A-4-2	Letter "Canadian Advanced Railbus" from V.H. Mizrahi (CN) to J.S. Busby (CANAC) 9 July 1986.
A-4-3	Letter A.M. Garlicki (NRC) to S. Vespa (TDC) 18 July 1986.

TRANSPORTATION TECHNOLOGY LIMITED
INTER OFFICE MEMORANDUM

To: Attendees

From: P.E. Timan

cc: Chrono - WP
CFD/R&D/9650

Date: 14 August 1986

Ref.: TTL/1539/86

Subject: **REVIEW SESSION - PHASE I INTERIM REPORT FOR THE DESIGN AND DEVELOPMENT OF THE CANADIAN ADVANCED RAILBUS**

MINUTES OF MEETING

DATE: 9 July 1986

PLACE: AII Transportation Technology Limited, Kingston

ATTENDEES:

Arjan Chandan	Transport Canada	Chief, Pass. Policy & Program
M.S. Hryszko	TDC	Senior Development Engineer
M.S. Krishnamurthy	Transport Canada	Planning Officer
S. Vespa	TDC	Senior Development Engineer
Louis Doyle	Ministere Des Transporte Du Quebec	Agent de Recherche/Avocat
Tom AppaRao	Ont. MTC Rail Tech. & Systems Office	Manager
Wilf Walker	Ont. MTC Rail Office	Sr. Trans. Officer
Joe Chisholm	CTC	Director, Maintenance & Standards
Pierre De Villers	VIA	Director, Eng. Services
Nicholas Vincent	VIA	Manager, Light Rail
Andrzej Garlicki	NRC	Research Officer
J.H. Stannard	TTL	Director, New Products
P.E. Timan	TTL	Project Engineer, Railbus

EXPLANATORY NOTE:

The following only reflect 1) the events which occurred at, and/or 2) the actions to be taken as a result of the meeting referred to above, as they were recorded by the party whose signature appears as having prepared the minutes. These minutes do not reflect the creation or modification of any contract documents or obligations which can only be accomplished by formal amendment to the contract documents.

SUMMARY:

The attendees were met at the VIA Rail Kingston Station by TTL staff, and were transported to the Transportation Development Center in a Motor Coach Industries (MCI) 102 A3 (3 axle version) Intercity Bus. A sister to this bus, the MCI 102 A2 (2 axle version), is proposed as the baseline vehicle for modification by TTL into a Railbus. The short trip from the VIA station to UTDC provided an excellent introduction to the day's discussions.

After arriving at UTDC, the attendees were able to view engine, accessory and baggage bays before assembling for the review meeting.

Dr. J. Stannard (TTL) opened the meeting and welcomed those present.

S. Vespa (TDC) followed with a brief introduction to the global Railbus program being administered by TDC in which he outlined progress to date in the following areas:

- Winnipeg Coach Sales and Service (WCSS) Railbus test vehicle design and development in Manitoba;
- WCSS Railbus testing by TTL in Thompson, Manitoba;
- WCSS Railbus demonstration by TTL;
- BREL Railbus trials with CN and VIA;
- BREL Railbus demonstration with VIA.

The meeting then progressed to the technical aspects of the Railbus Phase I tasks, essentially following the progression in the Interim Report. The presentation of this portion of the meeting was shared between Dr. J. Stannard (TTL) and P. Timan (TTL) and can be reviewed by referring to the Phase I Interim Report and the attached copies of the overhead slides viewed during the discussions.

The discussion and comments arising from this presentation are highlighted in the following paragraphs.

The presentation was interspersed with discussion. A session with comments on the report wrapped up the meeting. The attendees were thanked for their participation and comments, and the time spent in reviewing the Phase I Interim Report. The MCI 102 A3 Intercity Bus was again used to transport the attendees to the VIA Station.

DISCUSSION:

Introduction and Overall Methodology

During the discussion of the overall methodology selected to design and develop a Railbus for Canadian Remote Service, concern was voiced with respect to the crash worthiness of the Railbus. The concerns were centered around the absence of a traditional railroad underframe structure, and collision posts. The position held by TTL was that the optimal design for passenger safety is to limit the acceleration levels in the passenger compartment by providing controlled collapse of the ends of the vehicle while maintaining a survivable compartment volume. This would require additional analysis and verification in subsequent Phases of the program. It was generally concluded that blindly designing for AAR buff loads was not practical for this type of application and that further study was required.

S. Vespa (TDC) commented that crashworthiness investigation was a project being considered at TDC with a view to provide design criteria for all future railroad equipment based on vehicle weight and operating characteristics. A decision on this program is expected to be concluded by early 1987.

Background Review, Service and Regulatory Requirements

Errors were discovered in Table 1 "Railbus Manufacturers and Design Details" on page 10 of the Interim Report. These errors included incorrect heights of the various Railbus vehicles, Ganz-Mevag has single and bogie is a double ended vehicle which is not optional and the number in service is 13. TTL will review the entire table and make the necessary corrections.

There was general agreement with the service requirements with the exception that the estimated market for the Regional Service type of Railbus would be closer to 140 rather than 60-80 units. Handicapped access was highlighted as a basic requirement for Railbus technology. It was noted for information that an MCI bus has been modified with a wheelchair lift to provide handicapped access under an unrelated project with TDC, and is presently in demonstration service. In addition, MCI has received orders for 10+ buses with this feature from bus operators in the U.S.

A passenger access door on both sides of the Railbus was considered beneficial, but not necessarily a requirement for remote service applications. However, concern was raised with respect to the need for a crew door at the "B" end of the vehicle to facilitate switching operations.

For the prototype Railbus, the addition of a crew access door is feasible, but since the production vehicle is recommended to comprise a pair of back to back vehicles, this feature was not incorporated into the single vehicle demonstration prototype design. TTL will review the need for this feature in the prototype as well as passenger door access from both sides of the vehicle.

Design Studies

Comments were as follows:

- Due to unequal load distribution on the front and rear axles, stability and curving should be checked in both directions.

- The proposed intervehicle connection of a married pair was considered crude and needed work. TTL agreed but stated that design of this passageway was out of the scope of the present contract to design, build and test a prototype Railbus. Concern was particularly directed toward passenger negotiation of this passageway.

Preliminary Design

The following comments were made pertaining to the discussion of the preliminary design drawings.

- The per-axle load for the MCI/TTL Railbus was very low (about one half of BREL) which may result in some difficulty when signalling tests are performed. TTL has, in part, attempted to minimize this possibility by providing tread brakes in order to ensure clean wheel tread surfaces.

- Maintenance of the vehicle was considered of prime importance in Remote Service. This was the main driving force behind TTL's decision to utilize automotive technology to the greatest extent possible so that local mechanics could service the Railbus, and spare parts would be readily available. Those components such as the wheelsets, brakes and suspension which required railroad type equipment in order to handle the high shock environment, were also designed with simplicity and maintenance in mind.

  Where local mechanics were not available, it was suggested by J. Chisholm, that, a mobile maintenance team could be employed to maintain Railbus vehicles over large portions of the system. This would eliminate the need for dead heading to a major center for repairs.

- Concern was raised with respect to the location of the toilet at the "B" end of the vehicle, as it blocked a significant area of the driver's vision on his left side.

  It was suggested that the toilet be placed behind the driver to alleviate this problem. TTL commented that the relocation was probably feasible, but that it would add cost to the prototype vehicle, whereas, this feature would not be of concern on a production married pair.

General Comments

The attendees were requested to send their comments to S. Vespa (TDC) in writing with regard to the Interim Report and/or any other aspects of the Railbus concept. These comments will be used to update the Interim Report for final release. Minutes were to be prepared by TTL and distributed to the attendees.

It was noted that there is an inconsistency in the use of the terms "mass" and "weight" in Appendix IV of Attachment A-3. TTL will review and correct these errors.

It was suggested that the cost of the baggage trailer may be low depending on the type and volume of freight carried. TTL stated that the figures shown represent a simple trailer based on a "WICKHAM" type track vehicle, but were suitable, a "delux" freight trailer could be provided by the second vehicle of a married pair fitted for freight handling.

P.E. Timan

Attachment

:dmm

CN RAIL

Internal Correspondence

Correspondance interservice

Department, place and date Service, lieu et date: M.P. & C.E. - Engineering, Montreal 1986 07 09

Your file/Votre dossier

and letter dated/et votre lettre datée du

Our file/Notre dossier: BQ 5040-5-2

Subject/Objet: **Canadian Advanced Railbus**

Mr. J.S. Busby
Executive Consultant
Canac Consultant Ltd.,
700 Dorchester Blvd., Floor 5,
Montreal, Quebec

The following recommendations regard the phase I interim report for the "Design and Development of the Canadian Advanced Railbus".

1) Headlights:

CTC general order O-14 should be maintained as a minimum. Train crews, vehicle drivers on crossings, and persons in the vicinity of railway tracks are accustomed to this headlight intensity. Reducing headlight intensity will reduce warning time, and may mislead persons accustomed to a given light intensity - distance relationship.

2) Protective Cab:

A fully enclosed cab is necessary to ensure the safety of the crew, passengers, and vehicle. This should also reduce the possibility of passenger noise interfering with radio communication.

3) Horn:

The horn should be a three tone type and should be located on the roof of the railbus to allow for better sound propagation. A "K-3" horn should be used for reasons identical to "1" but with reference to sound intensity.

4) Underframe Strength:

The possibility of collisions with railway vehicles or road vehicles on crossings make it necessary for the railbus to have an underframe and anti-climbing arrangement to protect the crew and passengers.

....2

A theoretical analysis which takes into account the lighter weight of the railbus, as compared to existing railway equipment, shows that an underframe capable of withstanding end loads of 400,000 lbs, without developing any permanent deformations, is necessary. This can be attained with the addition of a relatively light centre sill underframe member.

5) Collision Posts:

For the safety of the crew and passengers the railbus should include collision posts to prevent end-shearing. Two main vertical members, as per AAR Vol. A-III, should be installed at each end.

6) Air Brake System:

The air brake system should be designed to meet CN requirements (as described in previous correspondence) and remain unaffected by the use of the horn or other air operated devices. Compatibility with other railway equipment is desirable.

7) Compatibility to Hot Box Detectors:

Design of the suspension box frame (truck) should allow hot box detectors to read each bearing temperature.

for: V.H. Mizrahi
Chief of M.P. & C.E.

17SB010wg

National Research Council Canada
Conseil national de recherches Canada

Division of Mechanical Engineering
Division de génie mécanique

Ottawa, Canada
K1A 0R6

File / Reference 3730-3

CDT
TDD 1465-425-7

To/À	Date	Init.
S. Vespa	23/7	

18 July 1986

Mr. Sesto Vespa,
Senior Development Engineer,
Transportation Development
Centre,
Transport Canada,
Suite 601, West Tower,
200 Dorchester Blvd. W.,
Montreal, Quebec.
H2Z 1X4

Dear Sesto:

As per your verbal request for written comments regarding Phase I of the design and development of the Canadian advanced railbus, I would like to draw your attention to the following:

(a) TTL Report No. 338-610-002 (included in Report No. 338-992-001), p. 63 of 69. The mileage accumulated is correct numerically; however, since 1 kilometer equals 10^6 millimeters, and not 10^5 as shown, then, either the mileage accumulated was only 334.7 km, or the hubodometer reading should be 1,165,430, and not 116,543 as shown.

(b) TTL Report No. 339-410-001 (included in Report No. 339-710-001), Appendix IV, p. 2 through 5 of 8. The proposed changes to this text are marked in red to have it in agreement with the SI system of measurements and the traditional way of expressing weight in "kilograms-force".

Thank you very much for inviting me to attend the Review Session on Phase I Interim Report for the design and development of the Canadian advanced railbus, which took place last Tuesday.

Canada

It was a pleasure, Sesto, meeting you on this occasion, and I hope that our paths will cross in the not too distant future.

Sincerely yours,

A.M. Garlicki
Vehicle Dynamics Laboratory

AMG:ag

Encl.

JUL 20 1987
Transport Canada / Transports Canada